UNIVERSITY GEOLOGICAL SURVEY

OF

KANSAS

THE UNIVERSITY

GEOLOGICAL SURVEY

OF

KANSAS.

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Kansas. Univ. Geol. Survey.

By ERASMUS HAWORTH
AND ASSISTANTS.

VOL. I.

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MEMBERS OF THE UNIVERSITY GEOLOGICAL SURVEY.

F. H. SNOW,
Chancellor, and *ex officio* Director.

S. W. WILLISTON,
Department of Palaeontology.

ERASMUS HAWORTH,
Department of Physical Geology and Mineralogy.

E. H. S. BAILEY,
Department of Chemistry.

FOR VOLUME I.

ERASMUS HAWORTH, Geologist.

JOHN BENNETT, Assistant Geologist.

GEORGE I. ADAMS, Assistant Geologist.

M. Z. KIRK, Assistant Geologist.

E. B. KNERR, Assistant Geologist.

JOHN G. HALL, Assistant Geologist.

Dr. F. H. Snow, Chancellor of the University of Kansas:

SIR—I have the pleasure of submitting to you the following report on the stratigraphy of the Carboniferous of Kansas and allied subjects, which will constitute volume I of the rereports of the University Geological Survey of Kansas.

Very truly, ERASMUS HAWORTH.

DEPARTMENT OF PHYSICAL GEOLOGY AND MINERALOGY,
UNIVERSITY OF KANSAS, NOVEMBER, 1895.

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PREFACE.

The act of the Kansas Legislature in 1889 making appropriations for the current expenses of the State University included a provision that a geological survey of the state should be one of the functions of the University. In 1895 the Board of Regents of the University, by special enactment, declared the State Geological Survey organized, and the Chancellor of the University was made its director, *ex-officio*. Prof. S. W. Williston was placed in charge of the department of Paleontology, Prof. Erasmus Haworth of the department of Physical Geology and Mineralogy, and Prof. E. H. S. Bailey of the department of Chemistry. Active operations along the line of a geological survey, however, were begun in the summer of 1893, under the direction of the department of Physical Geology in the University. Arrangements were made by which advanced students in this and other institutions might receive credit in the University for work done while engaged upon the survey. Mr. M. Z. Kirk, of Iowa, Mr. W. H. H. Piatt and Mr. C. E. McClung, students of the University, were put into the field for the summer. Mr. Kirk ran a section along the Neosho river from the south line of the state to its source, and along the Cottonwood river to Clements, a report of which constitutes chapter III of this volume. Mr. Piatt did considerable areal work in tracing the outcroppings of certain formations and in studying the conditions along the Verdigris river. Mr. McClung devoted a number of weeks to an investigation of the coal mining areas, principally in Cherokee and Crawford counties, and in the preparation of a map locating the various coal mining plants. This map has not yet been published, but has already had considerable additions made to it and will ultimately form the basis of a mining map for the southeastern part of the state, to be published in volume III of these reports. The writer spent considerable time during the same summer in assisting the three gentlemen named

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Dakotah; Prof. J. H. Harnley. also of McPherson, likewise traced the boundary between the Dakotah and the Fort Benton formations from the north line of the state to as far south as Lincoln; Mr. W. N. Logan, a student of the University, ran a section near the north line of the state from the Permian to the western boundary in Cheyenne county, and one along Smoky Hill river from the western side of the state to the eastern limit of the Fort Benton, in addition to which he did considerable detail work in the extreme northwestern part of the state in connection with the work done for the State Irrigation Board, and also continued the boundary between the Dakotah and the Fort Benton from Lincoln to the Arkansas river. Mr. M. Z. Kirk has devoted about two months to field work in connection with the study of salt and salt deposits of the state, a problem which has been assigned to him for special investigation. It is hoped that we will soon be able to issue his report, probably as a part of volume III, giving a detailed account of the geology, chemistry, and technology of the salt deposits and salt industries of our state.

During the earlier part of this season the writer gathered considerable new information concerning the oil and gas deposits of the state, but later found it necessary to devote all of his time to a general supervision of the field work. This required extensive traveling all over the state and a more or less minute knowledge of the workings of each party and the detailed conditions surrounding them. He is, of course, to a great extent responsible for the results obtained and the conclusions reached by the individual assistants, but in no wise would he detract in the least from the value of their results, or the ability shown by each. It should be stated that in the organization of the survey as above mentioned it was contemplated that the work of the various assistants should be done without financial compensation, as no provisions have been made by the Legislature for such. Few, if any, instances can be found in the annals of America where so many able men have contributed so much of their time to the material development of their state. Our state as a whole is the gainer, but it should not forget their generous gift of time and ability.

Finally, acknowledgments are made and sincere thanks returned

to the many persons not already named who have assisted in the preparation of this volume; to Chancellor F. H. Snow and the Board of Regents for their assistance and warm interest shown in the work, to the various companies and individuals who are prospecting for oil, gas and other products in various parts of the state and have in that way drilled deep wells all of whom have uniformly responded to my every request with great kindness and manifested the greatest interest and willingness to assist in the work undertaken; to the various railroad companies operating in the state, especially to the Atchison, Topeka & Santa Fe, the Chicago, Rock Island & Pacific, and the Union Pacific for assistance rendered; and finally to Miss Hattie M. Huntsman, Mr. R. W. Carter and Mr. H. H. Johnson for the skillful manner in which the many drawings were made that accompany the report.

E. H.

University of Kansas, November, 1895.

OBJECTS AND PLANS.

By the organization of a University Geological Survey of Kansas a full and complete geological survey of the state is contemplated. The work will necessarily have to be done with relative slowness, which may not prove to be a disadvantage. It is expected that it will be done by the members of the University faculty, their advanced students, and other individuals, citizens of the state or otherwise, who are willing to give their time and energies to the state a few months of the year in assisting to carry on investigations interesting and scientific in character, and valuable in many ways in their results, the compensation for which is to be an increase in the knowledge of nature, an opportunity to study geology in the field, a medium of publication by means of which they may have their labors brought before the world, and a consciousness of having added a mite to the "increase and dissemination of knowledge among men." Since the University has opened a graduate department in geology and paleontology it may not be a vain hope that the Survey will help to build up these departments, and thereby produce a reactionary good in addition to those above named.

It is contemplated by the Board of Regents that the interested departments in the University will severally be responsible, not only for the work accomplished under the departments, but for the degree of energy and zeal with which it is prosecuted. Each will therefore be expected to issue reports from time to time on the work done, reports covering greater or lesser subjects or natural divisions of the great science of geology. At the outset it was agreed by all that the investigations in general stratigraphy, areal boundaries, and allied subjects should be taken up first, after which other divisions should follow in natural order.

The present little volume is the first result of the execution of the plans just outlined. It has been prepared by the Department of

Physical Geology, only such features of Paleontology being used as seemed to be a necessary adjunct. It covers the whole of the Coal Measures and the Permian of the state, and is general rather than detailed, yet not generalized to any degree. That is, the various accompanying plates are all drawn to an exact scale, and represent conditions actually revealed on the surface or beneath the surface by deep borings. No "generalized" or "composite" section is given excepting plate XXII a generalized section of the Carboniferous and figure 11 in the text. It is fortunate that the recent activity in prospecting for oil and gas in the state was begun prior to the organization of this Survey. We now have positive knowledge regarding the underlying stratification for a large area in the eastern part of the state which otherwise could have have been known only by inference.

A report of the work done the past summer for the State Board of Irrigation will appear under the auspices of that Board, but quite naturally a great deal of stratigraphic and general geologic data were gathered which can best be used by this Survey. It is hoped that by the close of another season we will be able to prepare a companion volume giving the stratigraphy of the Cretaceous and the Tertiary in a similar manner, a large portion of the material for which is already obtained. Considerable progress has likewise been made on a third volume to be devoted principally to economic questions, including a detailed account of the geology, technology chemical and physical properties, and economic importance of the coal, oil, gas, salt, and gypsum of the state. This may very naturally be followed by a report on the building materials, mineral paints, soils, mineral waters, etc., on all of which some work has been done, but not enough to admit the formation of definite plans regarding the report. The department of Paleontology has likewise already accumulated large quantities of materials, so that within a year or two it will be able to issue a report on the paleontology of the state which, from every consideration will be an important series of volumes. For as is well known, our state is exceedingly rich in both animal and plant remains.

It cannot be decided what particular lines of detailed investigations will be taken up after the general ones above mentioned shall

have been completed; possibly detailed descriptions by counties, or by areas limited by latitude and longitude; possibly the policy will be to follow themes rather than areas. In any event it is proposed to be sufficiently deliberate to insure scientific accuracy, and yet sufficiently rapid to bring the important discussions before the citizens of the state with expedition so that benefits may be realized early.

For the present at least the octavo volume will be the style of publication adopted. Bulletins, the recent form of overflow publications so generally adopted in America, are unnecessary, because our University Quarterly, a regular publication, meets such requirements.

It should be remembered by the scientific reader that these reports are intended primarily for the masses of the citizens of Kansas, and that therefore an elementary character must be preserved, not however, it is hoped, at the expense of scientific accuracy. Divers elementary explanations must be given, and rudimentary principles, however well known to the scientist, must be elucidated, even to the frequent repetition of long used illustrations. But it is earnestly hoped this will not result in unnecessary repetitions, or in any other act which may give them a "padded" appearance.

INTRODUCTION.

In order that the general reader may the better understand the following chapters, a brief introduction to the general physiographic and geologic conditions of the state may not be out of order. Kansas is a part of the great plain stretching from the Mississippi river on the east to the Rocky Mountains on the west. It is approximately 200 by 400 miles in extent, and should be looked upon as a block in the great plain, constituting an essential part of it but not specially different from other portions lying on either side of it. The elevation above sea level of the eastern end averages about 850 feet, with Bonita 1,075 feet, about the highest point, and Kansas City 750 feet at the Union depot, the lowest. The north and south boundaries have approximately the same elevation, although the increase in height is more rapid along the northern side from the Missouri river westward, while on the southern side the rapid increase in height does not begin until farther west. The lowest part of the state is the Verdigris river valley where it crosses the southern line. At the Missouri Pacific depot in Coffeyville the elevation is 734 feet, 16 feet below the Union depot at Kansas City. The southern line crosses the great ridge west of Independence, the Flint Hills, which lifts the elevation to over 1,700 feet, but it again declines westwards towards the Arkansas river to an elevation of only 1,066 feet at the Santa Fe depot in Arkansas City. From here to the southwest corner of the state the ascent is gradual, increasing slightly with the distance, so that for the western hundred miles across the whole of the state the eastern descent is from 7 to 12 feet to the mile. The western boundary line varies slightly from north to south but is close to 4,000 feet above sea level, sometimes being slightly more and again a little less.

The drainage of the state is therefore to the east. Here and there an irregularity of surface will deflect the stream southeast or

south, as the Verdigris river and the Blue river, or northeast, as with the Republican river through a part of its course, and the lesser tributaries to the Missouri in the northeastern part of the state. The streams usually have a considerable current due to the great incline of the surface as a whole which, from west to east, averages nearly eight feet to the mile for the whole state. Towards the eastern part of the state they have broad and level valleys filled in to from 20 to 60 feet with alluvial material, while in the far west some of them have scarcely reached base level.

The general physiographic conditions of the state are not as regular as is usually supposed. Although the surface is a great plain sloping eastward, its minuter topography is often varied and rugged; valleys 200 feet deep, bluffs and mounds with precipitous walls 300 feet high, overhanging rocky ledges, and remnants of cataracts and falls in numerous streams giving a variety of scenery, are to be observed almost all over the eastern part of the state, and to even a greater extent in some parts of the west. The physiography of a country is dependent upon its geologic structure, so that we may begin physiography by a study of structural geology.

The geologic structure of Kansas, when considered on a grand scale, is simple, but in detail often becomes complex and difficult. In the extreme southeast part of the state over an area not exceeding 30 square miles, dense limestones and interbedded chert rocks, with the residual products produced by their superficial decay, constitute all that is to be seen of the geologic formation. These limestones and cherts extend westward as far as prospecting with the drill has yet shown their presence or absence, constituting the floor upon which rest all of the remaining parts of the rock formations of the state. Could we examine below this floor we would find that it in turn rests on other rocky layers and they on others for a distance of about 2,000 feet, at which place the penetrating drill would reach the solid granite or gneiss or shist below which no limestones or sandstones or shales could be found. But the limestone and flint beds above mentioned are the floor for the Kansas formations, and may well serve as a limit to our present investigations. In the eastern part of the state this floor universally dips to the west, the southwest or northwest, varying in places to a considerable

extent, but being moderately uniform, and the superimposed strata one above the other follow this inclination. This westward dip of the strata and the eastward dip of the surface serve to bring the succeeding strata individually to the surface like the ends of shingles in the house roof. As we pass westward the surface rises from the horizon but rises doubly fast from the limestone and cherty floor, so that could we dig a trench from the eastern line of the state westward following the surface of the floor, it would rapidly become deeper and in its walls would be exposed the successive layers of rock one above the other as they actually occur. But the westward sloping of the strata is not continued throughout the whole state. Scarcely has one-third of the distance been passed until the order is reversed. The eastern part has been influenced by the great inland swell of the Mississippi valley, the Ozark Hills. while the western part has been more mightily influenced by the great Rocky Mountain uplift. Could we continue our trench westward to the western side of the state we might find that the limestone and cherty floor extended that far, but most probably long before that distance was reached it would pass into rocks of other character. Of this matter, however, we are in total ignorance, as no boring has yet been put down deep enough to throw any light on the subject; but the lines of stratification marked on the walls of our trench would change their direction and incline eastward instead of westward.

The different rocky strata now found lying one above another were formed at different times. It is desirable as a matter of convenience to assign names to the different time periods and to the different great divisions of the rock strata in order that we may converse intelligently about them. In the history of the rise of the science of geology we find different customs have been followed at different times and by different people, so that there has not been a perfect uniformity in the choosing of names for time periods or for rock formations. But as the science grows older this disparagement of usage will gradually grow less. In 1889 the United States Geological Survey* decided upon a certain series of names to be given to the great time periods, which in general correspond with the

*Tenth Annual Report, Director U. S. Geol. Surv., p. 65; Washington, 1890.

usages of standard text-book makers, but which, in a few particulars, differ somewhat from that usually observed in other publications. They divided all geologic time into 11 periods and gave the following names and limitations:

"The first (the latest) period shall cover the time beginning with the first ice invasion and continuing until the present, or that which is commonly called the Quaternary." This was called the Pleistocene.

"The second period shall include the time divisions sometimes called Pliocene and Miocene. Its earlier delimitation shall be that indicated by paleontology, and its latter the first ice invasion of the Pleistocene; and its designation shall be Neocene."

"The third period shall be the Eocene. . . . Its definition shall be that commonly accepted by paleontologists and geologists as determined by fossil remains."

"The fourth period shall be the Cretaceous. Its definition shall be that indicated by paleontology and usually accepted."

"The fifth period shall include the time divisions known as Jurassic and Triassic, and shall be designated Jura-Trias. Its definition shall be by paleontology."

"The sixth period shall be Carboniferous, including the subdivision sometimes called Permian. Its definition shall be by paleontology."

"The seventh period shall be the Devonian. Its definition shall be that indicated by paleontology and usually accepted."

"The eighth period shall include the time divisions sometimes styled Upper Silurian and Lower Silurian and otherwise styled Silurian and Ordovician. Its definition shall be by paleontology, and its designation shall be Silurian."

"The ninth period shall be designated the Cambrian. The definitions of its upper limit shall be by paleontology. . . . Its lower delimitation shall be the time of deposition of the lowest rocks thus far known to yield a well defined fauna."

"The tenth period shall be the time of deposition of plastic rocks older than the Cambrian. . . . ."

The eleventh: "The oldest time division shall cover the time of formation of the ancient crystalline rocks, and its designation shall be Archaean."

Of the above mentioned geological column, Kansas geology deals only with the Carboniferous and younger rocks excepting as we may penetrate far below the surface of the earth by drill or imagination

to consider those which lie beneath the great floor already mentioned. The portion of the column above the Devonian is well represented in our state. The little corner of crystalline limestone and chert in the southeast part of the state represents the lowest member of the Carboniferous, which was formerly called the Sub-Carboniferous, but for which term Mississippian as suggested by Williams* has come into general use. Above, the Coal Measures proper are developed to a thickness of from 2,500 to 2,750 feet, and the Permian to the thickness of 795 feet. Above the Carboniferous, over portions of the state, a small amount of Jura-Trias is found, while the Cretaceous is extensively developed over more than one-third of the state. Still above the Cretaceous, in the western part, covering an area equalling nearly one-fourth of the state, a heterogeneous deposit of sand, gravel, clay, soil and other loose materials occur in great abundance. This has generally been called the Teritary, yet it may yield to subdivision into the Eocene and Neocene to conform with the classification above quoted. In the northeastern part of the state are extensive deposits of the glacial drift material which constitutes an important part of the Pleistocene, and again in the Tertiary area of the west the looser sands and gravels have unmistakably been worked over and modified in recent times, and soils and gravels have accumulated over other parts of the state, so that the Pleistocene formations practically mantle the whole of our area. As this report is confined entirely to the different members of the Carboniferous formations, no attention will be given to the minuter classifications of the formations above it, while the subdivisions of the Carboniferous will be given in the body of the report.

As the Carboniferous rocks are composed of alternating beds of limestones and shales, the latter of which frequently grade into sandstone, it has been deemed advisable in making the drawings for the plates illustrating the great sections, run in different directions, to insert nothing but the limestones, leaving the blank spaces between for the shale beds with their included sandstones. The limestones are extensive and persistent, and may well be likened to great shelves placed one above another in the underlying portions

*Williams: U. S. Geol. Surv., Bul. 80, p. 135; Washington, 1891.

of our state. Could one transform the shale beds and sandstones into a transparent medium, by standing near the southeast corner of the state and looking to the northwest one could see the limestone shelves reaching far back to the west dipping gently in the direction they extend dividing the volume considered into stratum above stratum of relatively thick shales and sandstones separated by the thinner limestones which, here and there, increase to double the normal thickness, but which have great lateral extent and are remarkably even and regular in comparison with their length and breadth. The eastern limit of these several shelves would gradually progress westward from the bottom upwards. Were the surface uniform the limits or the outcroppings would be parallel lines. But with the river valleys cut deep into the surface and the high mounds and table lands constituting the ridges, it will readily be seen how the eastern limit of each individual shelf must necessarily be a sinuous line, each, while trending from northeast to southwest, may be exceedingly uneven in direction. Wherever the limestone is reached, however, a greater or less escarpment is produced by the wearing away of the softer shales beneath, the height of which is usually dependent upon the thickness of the shale beds. When those become thinner, that is, when the shelves in our model approach closer together, the escarpment becomes less and usually the outcropping is carried farther to the east; for the weathering agents can wear away a thick bed of shale that is capped with limestone more readily than it can a thin one. If we travel from the east towards the west, therefore, we are constantly passing upwards from one shelf to another, from one escarpment to another, with the limestone shelves lying on top of each other. On the map, plate XXXI, an attempt has been made to represent this condition, by giving a semi-perspective view of the block, Kansas, of the great Mississippian plan. On the south and east vertical walls are represented on which are traced the sections of the walls with the several limestone shelves above mentioned. On the surface of the map the southeastern outcropping of the same shelves are marked and the irregularities in the lines are produced as above explained, while when they approach nearer together it is always due to a thinning out of the shale bed between the two limestone shelves.

It has been thought best to give individually an account of the conditions observed along each line of section so that the reader may see and handle the evidence upon which the greater conclusions rest which will be brought in after these several detailed descriptions are given.

CHAPTER I.

A GEOLOGIC SECTION FROM GALENA TO WELLINGTON.

BY GEO. I. ADAMS.

This section begins at the state line in the eastern part of Galena. Here, the Mississippian or Sub-Carboniferous ore bearing limestone series is exposed and for a few miles to the west. The surface declines rapidly towards the west to Spring river, a distance of about three miles, beyond which it rises again slightly and reaches the Coal Measure formation about four miles from the state line.

THE MISSISSIPPIAN SERIES.

This series consists principally of a dense, crystalline limestone carrying excessive quantities of chert, or flint rock, which is very irregularly disseminated through it. In places it is partially composed of shale, but the limestone and chert are the characteristic constituents, as is abundantly shown throughout the lead and zinc mining region about Galena, Joplin, and other mining towns.

The surface of the Mississippian series is quite irregular, indicating a long period of erosion between Mississippian and Coal Measure time.* This irregularity is shown in two ways.

* Haworth: A Contribution to the Geology of the Lead and Zinc Mining Districts of Cherokee county, Kansas, 1884. Transaction Kas. Acad. Sci., vol. 8, p. 13. Kansas Univ. Quar., vol. 2, p. 126.
Hay: Geological and Mineral Resources of Kansas, 1893, p. 5.

At different places in the vicinity of Galena and further east, in Missouri, numerous residual patches of Coal Measure rocks still exist. Some of them are preserved by hard superficial layers, but others owe their present existence to basins and valleys cut in the Mississippian rocks by erosion before the Coal Measure rocks were laid down. Into all such depressions the latter were deposited and have been protected sufficiently to preserve isolated patches to the present time. The opposition of this condition is noted in the hills or prominences of the Mississippian within the Coal Measures and abundantly shown in many places near the eastern limit of the latter. A few of these will be mentioned. On the high ground along the western line of section 7, township 33 north, 25 east, a well only 23 feet deep reached the Mississippian, while numerous wells of about the same depth on much lower ground to the east did not pass through the Coal Measures. Along the north line of section 12, township 33 north, 24 east, an exposure of the Mississippian covers two or three acres, while equally low ground to the east shows none of it. Six miles back from the boundary, or within five or six miles of Columbus, the Mississippian is exposed at the surface, or is reached in shallow wells over an area of four or five square miles. The rocks here so closely resemble the ore bearing rocks at Galena, that on different occasions miners have spent considerable time here in prospecting for lead and zinc ores. It would therefore seem that here in Kansas, as in Missouri* and Iowa† there exists a marked nonconformity between the Mississippian and the Coal Measure, a nonconformity due principally to the surface erosion of the former before the latter was laid down.

The surface of the Mississippian dips to the west along the line of this section at about 20 feet to the mile. By referring to plate I it will be seen that the surface of the highest hills at the state line is about 975 feet above sea level. The deep well at Oswego reached the Mississippian at a point about 400 feet above sea level. The wells at Stover and Mound Valley went to within 330 and 60 feet

*Winslow: Missouri Geol. Rep. vol. 1, 1891.

†Keyes: Iowa Geol. Rep. vols. 1 and 2, 1893-1894.

respectively of sea level without striking it; while the one at Cherryvale reached it at 180 feet below sea level. The distances to Oswego and Cherryvale are 27 miles and 54 miles respectively, with a dip of 21.6 and 21.4 feet to the mile, or an average of 21.5 feet for each place. Other deep wells further to the north and west at Neodesha, Fredonia, Thayer, etc., give similar results. Still further west a well at Wichita was sunk 1,950 feet without reaching it. From the general inclination of the surface rocks it may be inferred that westward from the Verdigris river the dip gradually decreases, but as no deep wells are recorded which have reached the Mississippian nothing definite can be stated.

Later in this chapter, in calculating the thickness of the Coal Measures, it is assumed that from Elk City west the inclination gradually decreases to about 10 feet per mile.

THE CHEROKEE SHALES.*

Immediately above the Mississippian lies the great bed of Cherokee shales. This is by far the heaviest and most important shale bed in the Coal Measure area of the state. It is about 450 feet thick, as shown by borings at Oswego, Girard and Fort Scott. The borings at Stover, Mound Valley, Cherryvale and Independence, all of which are drawn to scale on plate I, show that it maintains this great thickness westward to a remarkable degree, probably underlying the whole of the Coal Measures.

The Cherokee shales contain many beds of sandstone which are extensively used for building and flagging stones. They contain the most extensive and valuable coal deposits in the state, both as regards amount and quality, and they also afford the greatest quantity of oil and gas thus far obtained. At the base of the shales along the line of this section sandstone in relatively heavy layers is observable, limited in its westerly extent usually to not more than a mile in width. Wells at different places from one to three miles westward have passed entirely through the shales to the surface of the Mississippian without striking any sandstone whatever. Neither is the north and south extension of the sandstone very great, but it is believed that it can be found over about three-fourths of the area within the state.

*Haworth and Kirk: Kansas Univ. Quar. vol. 2, p. 105; Lawrence, 1894.

About a mile west from the border line a thin vein of coal has been found in different wells, usually varying from three to six inches. In a few places, however, near the same horizon coal from 8 to 10 inches thick has been found. This is particularly noticeable on the farm of Mr. C. W. Harvey, in the northeast fourth of section 13, township 33 north, 25 east. Further west other sandstone appears some of which seems to rest on or near the Mississippian surface. On the farm of Mr. Burrass in section 31, township 33 north, 25 east, a most excellent flagging stone is extensively quarried and used for sidewalks in Galena and other places. The limitations of this sandstone cannot be given, for it grades into shale in all directions. The highest portions of it reach perhaps 50 feet above the Mississippian, forming considerable ridges here and there in the otherwise almost level valley.

Above and to the west of this sandstone area the shale thickens to about 150 feet, over which is a sandstone system which usually, as now observable, is from 10 to 20 feet thick. It has served as a protection for the soft underlying shale, so that the topography of the country is strongly modified. The steep hillsides and flat-topped mounds are common, resembling in general characteristics those further west similarly formed with limestone serving as a protection instead of sandstone. This range of hills and mounds finally developes into a broad plateau forming the highlands midway between Spring river and the Neosho with Columbus about on its highest part.

A few feet underneath this sandstone a seam of coal is found in different places and has been mined locally in a dozen or 20 banks in Cherokee county. It is usually from 12 to 14 inches thick where mined, but thins out or entirely disappears so, that it is by no means continuous from bank to bank.

Passing westward from Columbus the high elevation of the country is maintained for eight or nine miles, from whence the surface gradually declines to the Neosho river valley. The sandstone beds which were so common east have entirely disappeared, so that there is nothing to cause any abruptness in the surface. This is well shown by the marked change in the character of the left bank of the Neosho river. Above the surface limits of the Cherokee

shales the river has pronounced banks or bluffs along the border of the river bottom. But as the Cherokee shales are approached the bluffs on the left bank entirely disappear, while those on the right are maintained several miles southward by the heavy beds of limestone of the Oswego system.

The Weir City-Pittsburgh coal does not extend as far south as Columbus, neither is it reached in passing westward to Oswego, but it exists so short a distance to the north that it was thought best to represent it in the drawings, plate I. Other smaller coal seams do occur along the line and are shown in the Oswego well. Those which appear in the surface of the Neosho river are also represented in this section, or in the drawings by Mr. Kirk, plate III.

In the creek bottom two miles south of Oswego a compact buff-colored limestone is exposed which is about 18 inches thick where it is observed, but is reported as being thicker in the adjoining areas. Above it coal is mined in strip pits quite extensively, the vein being from 12 to 18 inches thick. Immediately overlying the coal is a dark-colored limestone which seldom exceeds 12 inches in thickness and is referred to in the language of the miner as a "cap-rock." The heavy bed of shale which supersedes this is best seen in the river bank northeast of Oswego at the wagon bridge. Interspersed with the light-colored shale is a varying amount of sandstone, and occasionally traces of calcareous matter hardly abundant enough to be called a limestone. Above this we have six feet of black bituminous shale, which immediately underlies the first important limestone found in this section above the Mississippian. Above this, which is the lower member of the Oswego limestone, is a four-foot bed of bituminous shale well exposed in the St. Louis & San Francisco railway within the city limits. These two shale beds of black shale are of stratigraphic importance. They are jet-black in color and strongly resemble coal in general appearance. Within them in great abundance one can everywhere find little spheroidal concretions from one-half to three-fourths of an inch in diameter, within which are often found little *discina* shells, fish scales, or other organic fragments which have served as nuclei around which the shale-forming material has gathered.

The lateral extent of these black shales seems to be as great as

that of the associated Oswego limestone. They are very abundant in the environments of Fort Scott, on the high hills north of Pittsburgh, the hills between Pittsburgh and Oswego and southward toward the boundary of the state. On account of their usually strongly-marked characters, they are a great help in recognizing the Oswego limestone.

THE OSWEGO LIMESTONES.*

Above the upper black shale, just described, lies the upper Oswego limestone, so that the four-foot shale bed is between the two limestone systems. In the drawings, plate I, this intermediate shale bed is scarcely represented on account of its extreme thinness. These two limestone systems together have been called the Oswego limestone on account of their great prominence around Oswego, at which place they cover the surface of the country for miles around, and cap the high bluffs on the west bank of the Neosho river. To the northeast they are found on the row of hills reaching towards Girard. Their southeastern limit forms an exceedingly sinuous line, which passes about two miles to the north of Cherokee, half way between Girard and Pittsburgh, and reaches the state line not far from Mulberry. The valleys of the Drywood and Marmaton are cut through them into the Cherokee shales below, so that they are also found in many places in all directions from Fort Scott, where the lower system constitutes the Fort Scott cement rocks. On account of their prominence in this vicinity they might well be called the Fort Scott limestone, but as the former-mentioned name was introduced a year ago, it might be well to leave it for the present.

On the summit of the hills north of Pittsburgh the Oswego limestone is a little more than 1,000 feet above sea level, while at Oswego it is about 900. This would give it a dip in a southwest direction of about four feet to the mile. This is much less than the maximum dip.. From Oswego they dip to the west, the upper one being exposed all along the railroad in cuts and ravines almost to Stover, where it disappears beneath the surface. The last place at which it was seen is in the quarry just west of Labette creek. The

*Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 105; Lawrence, 1894.

well at Stover shows the upper one to be 21 feet thick, the lower one 24 feet thick. By reference to plate I it will be seen that along the line of this section the dip is 21.5 feet to the mile, this probably being the line of maximum dip. The Oswego or Fort Scott systems limit the upper surface of the Cherokee shales. According to drill records in the various sections included in this report these limestones occur at a quite uniform distance above the Mississippian and extend with a remarkable persistence underneath the surface of the southeast portion of the state. Along this section they are shown in the wells at Mound Valley, Cherryvale, and Independence, as represented in plate I.

THE PLEASANTON SHALES.

From Stover to Altamont the ascent of the surface is 76 feet in 6 miles, the space being occupied by a shale bed which thickens to the northeast and becomes the important Pleasanton shales that have produced so marked an influence on the topography throughout the environs of Boicourt and Mound City.

THE ALTAMONT LIMESTONE.

At the summit of the ridge at Altamont a limestone is found which takes its name from that place. It varies considerably, but is usually a rough stone not suitable for building purposes. The base of this system which overlies the heavy bed of shale is considered the upper limit of the Lower Coal Measures.* By reference to plate I it will be seen that the correlation of the records of the wells at Cherryvale, Mound Valley and Stover is unsatisfactory as regards the systems which occur between the Oswego and Altamont systems. Further work may reconcile the various data which came to hand too late to be of service in the field-work, by showing that some of the limestone are exposed between Stover and Altamont but eluded discovery because of the heavy covering of soil. The Altamont limestone extends to the west, dipping gradually until it finally underlies Mound Valley, at which place the drill record shows it to be 12 feet thick. Further north it underlies the town of Parsons.

*Chapter IX, this Report.

THE MOUND VALLEY LIMESTONE.

Northwest of Mound Valley is a row of hills about 120 feet high which are part of a chain extending across the country from northeast to southwest, forming a bold escarpment. They are capped with a heavy limestone which is worn thin on its eastern margin, but thickens westward to 10 or 15 feet. On account of its prominence here it will be called the Mound Valley limestone. It dips to the west passing under the surface at Cherryvale. At Drum creek where it is exposed at the St. Louis & San Francisco railway bridge a five-inch seam of coal is seen immediately beneath it. This system has a great lateral extent, underlying Cherryvale, Mortimer and Galesburgh, and passing northwest towards Erie.

THE INDEPENDENCE LIMESTONE.

At Cherryvale the contour of the country is marked by a chain of hills which are peculiarly characteristic of the topography of southeastern Kansas. They have become separated from the bluffs and stand as isolated hills, with Drum creek passing between them and the bluffs to the west. They attain an altitude of about 100 feet above the valley and are usually composed of a light shale containing a variable quantity of sandstone. They have all been originally capped with limestone, which has protected them from erosion. Those which retain this protecting cap have nearly flat tops, while those from which it has been eroded have assumed the ordinary rounded summit. They present all stages of degredation, from those with a well-preserved limestone cap to those from whose summits the limestone has been but recently removed, and finally to those whose rounded domes show that they have long been deprived of such protection. On the sides of many of these which retain the limestone caps degredation is progressing so rapidly that vegetation can scarcely obtain a foothold. The chain of hills extends to the northeast, and includes the Bender mounds. Tracing the limestone system which caps them to the northeast of Cherryvale it is found to be about 10 feet thick and was last seen four miles south of Thayer where it is exposed in a wagon road. It probably underlies the Thayer coal field, and is the first system reached by the drill in

the vicinity of Neodesha. From Cherryvale it dips rapidly to the west, and across Drum creek presents a bold ledge. On the divide between Cherryvale and Independence the limestone is exposed over large areas and is weathered out in immense boulders. Further west it is covered with sandstone and shale. It is exposed in the bank of Mouse creek, and at Independence forms the west bank of the Verdigris river, measuring 40 feet thick at the wagon bridge. On account of its prominence here it may be called the Independence limestone. It is exposed in Rock creek, south of Independence, then disappears under the surface. The greatest dip of this system is in the direction of the section and is 17 feet to the mile, this being greater than any other dip westward along the entire route.

THE THAYER SHALES.

Overlying this system is a heavy bed of sandstone and shales. It includes the Thayer coal, the coal a few miles southeast of Neodesha, the light vein mined south of Brooks and the coal in the hills south of Independence. They all probably belong to the same horizon excepting the Neodesha, which has a lower position, but is in the same shale bed. The shales thicken and widen from Thayer towards the southwest, and the included sandstones become heavy and durable, furnishing good building material which can be obtained from many local quarries. At Thayer the shales are about 100 feet thick. On account of their importance at that place in producing coal they have been named the Thayer shales.

THE IOLA LIMESTONE.

The Thayer shales are capped by a heavy limestone, which has been traced northeast and southwest to the borders of the state and is known as the Iola limestone. It is first seen in this section capping Table Mound six miles northwest of Independence. The size and importance of this mound as a landmark makes it worthy of a passing description.

Table Mound is 225 feet above the Elk river, which bathes its western base and separates it by a narrow valley from the main bluffs. It owes its great height to the thickening of the Thayer shales which equal 250 feet in this vicinity. The summit which is

so level as to have suggested the name, Table Mound, has an area of about 400 acres. The sides of the mound except to the south are quite precipitous. On the north where the ledge of limestone is 30 feet thick there are only two places where a man may descend. On the west and north it is well timbered, a number of cedars being interspersed with the usual Kansas forest trees. West of Table Mound the Iola system is found on the bluffs above Crane creek, and the railroad in ascending the valley of Gordon creek gradually passes above it. At the summit of the divide a light shale supersedes the system. It is not far below the surface on the descent to Elk City and is exposed in some places along the railroad. At Elk City the limestone has thickened to 112 feet according to the record of a drilled well on the bank of Duck creek.

Before proceeding further with a description of the section, reference should be made to the correlation of the drill records of the various wells along this part of the route which are published, drawn to scale, plates X to XIII, and to Mr. Bennett's section, plate IV, from Fort Scott west, which includes the Oswego system and reaches the Iola system at Moran. It will be seen that in Mr. Bennett's section the distance between the outcroppings of the Oswego system and the Iola limestone is 26 miles, and that the vertical distance according to the correlations is 600 feet, while from Oswego to Table Mound the distance is 50 miles and the drill would reach the Oswego systems at 950 feet below the Iola. In other words the members of the Erie system found east of Bronson in Mr. Bennett's section are separated to the south by a thickening of the shale beds, in consequence of which the lines of their outcroppings diverge to the southwest. There can be little doubt but that the Independence, Mound Valley and Altamont limestone systems are the equivalent of the Erie system above mentioned, they having been traced for nearly the entire distance between the two sections.

THE ELK FALLS AREA.

Continuing the description of the section west and above the Iola system, an area throughout which sandstone greatly predominates claims our attention. In the hill just north of Elk City a thin limestone system is found 90 feet above the railroad track. The

same system is exposed in the river at Oak Valley. Here a second limestone system is found in the hills, but it is very light. Further west it is exposed in the railroad cuts west of Longton, where it is not over two feet thick. It disappears two miles east of Elk falls. The shale beds carry heavy sandstone. At Longton, south of the river, a sandstone ledge has broken down into blocks five feet thick. Above this ledge the first important limestone system found above the Iola is reached. Half way to Elk Falls it shows in a ledge on the north side of the railroad, and is at least eight feet thick at Elk Falls. It is quarried and produces a good quality of building stone. The sandstone below it is perhaps the more noticeable along the route. At Elk Falls the Elk river descends nine feet over the more persistent portion of the ledge. It is from this fall of the river the town received its name. Above the limestone at this place another sandstone ledge is seen in the hills, and above it is a limestone system which develops into a bold ledge in the bank of Wild Cat creek.

The presence of heavy shale beds and sandstones in this area is made the subject of greater interest when the following facts are taken into consideration. The record, drawn to scale on plate XII figure 1, of the well drilled at Niotaze, and the records of the wells at Peru and Sedan 20 miles south of the section, as well as a hasty study of the geology along the Missouri Pacific railroad in that vicinity, show that there are no heavy limestone systems exposed in that locality or reached by the drill by a depth of less than 750 feet. The widening of the sandstone area in passing from Colony to LeRoy, Yates Center and Fredonia would indicate a thickening of the shale beds, but would not account for the sudden thinning out and disappearance in so short a distance of limestones as important as those found in the Cherryvale wells or the Fredonia well. Evidently a further study of this region and an extending of the field of observation into the border of the Indian Territory will be necessary before a satisfactory explanation can be given.

At Moline a limestone system is exposed just east of the town along the railroad in a quarry which furnishes material used for ballast. In passing over the hill to the west, which rises 200 feet above Moline, four limestone systems are found in ascending and

descending to Grenola. The lower one is quarried at Grenola for building stone. Under it in the bank of the Caney a 10-inch vein of coal is exposed. This is probably the equivalent of that mined further south at Leeds and is of about the same geologic horizon as the coal at Topeka or that of the Osage veins.

THE FLINT HILLS.

Grenola is situated at the eastern base of the Flint Hills, from which place westwardly they can be seen rising in even terraces to the height of 350 feet above the town, with Grand Summit, the highest point, five miles away. They trend in a general north and south direction, and occupy approximately the southern part of Chase county, the western border of Greenwood, Elk and Chautauqua counties, and the eastern portion of Butler and Cowley counties. Fall river, Elk river and Big Caney, which in turn are tributaries of the Verdigris, have their sources in the many small streams on the eastern slope of the Flint Hills. The streams on their western slope are the tributaries of the Walnut. The Cottonwood, a tributary of the Neosho, sweeps in a broad curve to the north around the head waters of these two river systems. The divide between these several streams, with its uneven configuration, is known as the Flint Hills. Further north the same formations are cut through by the tributaries of the Kansas river and give rise to the terraced bluffs which are characteristic of the country around Junction City and Manhattan. In the Kansas river territory, however, the sequence of rock systems is less rapid, each having a considerable lateral extent, so that the country rises gradually to the west rather than abruptly as in the Flint Hills. In the highest parts the Flint Hills are 1,550 feet above the sea level. The general direction of the ridge may be located on the map by the significance of the names of the towns of Flint Ridge, Summit, Beaumont and Grand Summit. In their southern portion where crossed by this section the valley of Grouse creek, extending in a general north and south direction, divides them into two ridges: the eastern are known as the Big Flint Hills, the western as the Little Flint Hills. See plate IX.

The Flint Hills owe their characteristic contour wholly to erosion, there being no evidence whatever of a disturbance of the strata, all

of which now occupy nearly horizontal positions with a dip to the west of about 10 feet per mile. They are characterized by even terraces and small canons and gulches. Along the top of the terraces, which are covered with scanty growth of grass, the various limestone systems are seen in parallel ledges, and are very conspicuous on account of their whiteness. Their eastern slope is more abrupt, partly because of the slight western dip, but principally because the great shale and sandstone formation already described which constitutes their eastern base contains a much smaller per cent. of limestone than the hills themselves, and therefore was much more rapidly carried away by erosion. Big Caney, which flows nearly parallel to the trend of the hills, has cut off a ridge of this material which may be compared to foothills, as shown in the section, plate I, from Moline to Grenola.

The Flint Hills derive their name from the large amount of flint which is found over their surface. Nearly all the limestones composing them contains some flint, and a few systems carry heavy seams of it. The weathering away of the solid portion of the limestone has left the included masses of flint strewn over the surface in such profusion that it seriously interferes with travel. The country is principally used for grazing; however many good farms are located in the creek valleys.

Burden is the highest point geologically found along the route; Grand Summit exceeds it in altitude, however. From the difference in altitude and geological horizon it will be seen that the average dip to the west is about 10 feet to the mile along this portion of the section. Further on the railroad rises over it again, then descends gradually to Winfield, following the course of Little Cedar creek. The ledges and terraces retreat to the north and south as the railroad occupies lower ground. In this region the shale beds are lighter and limestone relatively more abundant. Crossing the Walnut river the ledge in the bluff is the last place at which an important limestone is seen along this section. Above it in the railroad cut, the soil changes from black to red and descending to the valley of the Arkansas it becomes sandy. Just west of Oxford some thin limestone is found in the ravines and at Wellington there is a system from which stone six or eight inches thick are obtained.

Beyond the limits of this section at Argonia, on the Chikaskia river, which is considered the eastern limit of the Red Beds, a similar stratum about six inches thick occurs.

THE WELLINGTON AREA.

At Wellington, in sinking a well in searching for coal, the drill reached a bed of rock salt at a depth of about 350 feet. This is the first place at which rock salt was discovered in Kansas. It probably belongs to the same formation as that found further to the northwest in the vicinity of Hutchinson, Lyons, Kanopolis, etc. At Wellington the banks of Slate creek are composed of unevenly bedded light drab shale which is probably of Permian age. On top of this shale after it had been subjected to great erosion, beds of sand have been deposited, which probably are of recent age. The geology of this territory from the divide between the Walnut and Arkansas rivers is intimately connected with the salt deposits, and must be taken up in detail in the future work of the Survey.

GENERAL SECTION.

A general section of this route shows that the Cherokee shales which are exposed between Galena and Oswego are 450 feet thick. According to the drill records the vertical distance at Elk City from the upper surface of the Iola system to the base of the Oswego is 1,000 feet, the included limestone systems aggregating 325 feet. From Elk City west the thickness of the formations can only be estimated by surface indications and the general dip of 10 feet to the mile. Accordingly the vertical thickness above the Iola system and below the Cottonwood Falls is about 1,200 feet. The limestone systems up to the section in the Flint Hills given in this article have a total thickness of about 80 feet, the sandstone greatly predominating in this area. The limestone systems in the Flint Hill section aggregate 66 feet. Allowing for the thickening of the systems in the vicinity of Cambridge they will probably reach a total thickness of 100 feet. From the above data it will be seen that the total thickness of the Coal Measures and Permian along the line of this section is 2,796 feet of which 2,650 feet lie below the Cottonwood Falls system. The limestone systems aggregate 505 feet. The ratio

of the limestone to the total thickness is therefore about 1 to 5½ for the whole section above the Mississippian.

ADDENDUM TO CHAPTER I.

In connection with our study of the Permian in the southern part of the state Mr. C. N. Gould, of Maple City, Kas., has contributed a section along the Missouri Pacific railway from near Cedarvale to Winfield. This is an important addition to our knowledge of the Flint Hills. Crossing them as it does from 10 to 20 miles south of the foregoing section, we might reasonably expect the conditions to be somewhat different. As will be seen by reference to plate I, Gould's section contains much more limestone than is shown in Adams' section. A computation of the whole amount shows that along the Missouri Pacific railway more than half of the vertical distance as exposed along the surface is composed of limestone, while along the Santa Fe line a smaller portion of the entire mass of the hills is limestone. See figure 1, on page 32. The verbal description of this section is taken bodily from Mr. Gould's letter. See also plate I.

E. H.

A Geologic Section across the Flint Hills along the Missouri Pacific Railway, beginning near Cedarvale and extending to Winfield.

BY C. N. GOULD.

NOTE.—The following section is to be accompanied by figure 1, next page, and plate I. The section begins at the bottom of the column as exposed at Cedarvale and refers to the successive formations in ascending order until Winfield is reached.

SEC. I.—Two layers each 5 feet thick of cross-bedded, fine-grained sandstone colored with iron. No fossils discovered.

SEC. II.—Several massive beds of limestone 1 to 5 feet thick, not well exposed. Upper layers shaly and containing flint and chert. Fossiliferous. Many *Fusilina cylindrica* in flint.

SEC. III.—Finely laminated shale shading from yellow to blue and green, probably glauconitic. Barren.

Massive limestone.

Finely laminated shale, arenaceous above. Barren.

Massive limestone very fossiliferous, corals, crinoid stems, *Fusilina cylindrica.*

Finely laminated shale; barren.

Massive limestone, very fossiliferous; *crinoid, Spirifer sp., Fusilina cylindrica, Productus nebrascensis,* and broken shells.

Twenty-five feet of yellow shale grading into spongy rotten limestone; barren. Dendritic markings and calcite crystals near the seams.

SEC. IV.—Massive limestone 1½ feet. Shale 1 foot. Limestone ½ foot, and shale 2 feet.

SEC. V.—Three layers cherty limestone, very fossiliferous; calcite, *Fusilina cylindrica, crinoid* and a univale.

SEC. VI.—Fine shale; barren.

Two layers (1 and 1-6) of massive limestone with a 6-inch layer of shale between.

Twenty-five feet of shale.

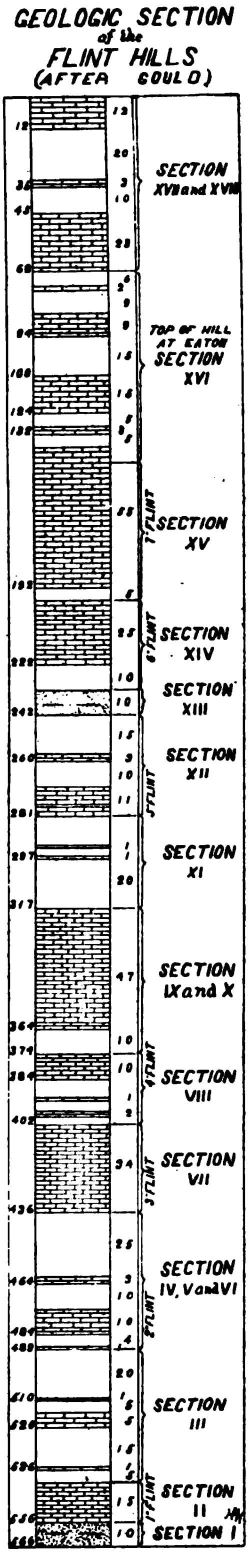
Five feet of massive limestone.

SEC. VII.—Twenty feet of hackly limestone much broken in all directions, and cherty especially toward the top of the beds. Calcite crystals marked; very fossiliferous, *Fusilina cylindrica.*

Two layers of massive limestone.

SEC. VIII.—Three feet of shale; 2 feet massive limestone; 4

Figure 1.


GEOLOGIC SECTION
of the
FLINT HILLS
(AFTER GOULD)
SECTION XVII and XVIII
TOP OF HILL AT EATON
SECTION XVI
SECTION XV
SECTION XIV
SECTION XIII
SECTION XII
SECTION XI
SECTION IX and X
SECTION VIII
SECTION VII
SECTION IV, V and VI
SECTION III
SECTION II
SECTION I

feet of shale; 1 foot of massive limestone; 8 feet calcareous shale, *Chenates* abundant; slightly cherty limestone.

SEC. IX.—Ten feet of shale blue and yellow; 17 feet massive and shaly limestone, fossiliferous; 10 feet of shaly limestone.

SEC. X.—Five feet layer of limestone with a layer of blue shale; 15 feet massive limestone with two layers of green glauconitic shale.

SEC. XI.—Yellow to drab shale and shaly limestone, very fossiliferous, *Productus nebrascensis, Myalina permiana, Myalina kansensis, Athyris subtilita*, crinoid, *Aviculopecten occidentalis, Pseudomonotis hawni*, Lamellabranchs.

Two layers massive limestone, 1 foot.

Red clay shales, barren, 4 feet.

Massive limestone, 1 foot.

Red clay, barren, 4 feet.

Green and blue shale, 6 feet.

SEC. XII.—Massive limestone. Green shale. Massive limestone with flint and fossils. Red clay shale, barren. Massive limestone. Clay shale, red.

SEC. XIII.—Red sandstone No. 2 near top of hill at Hooser; sandstone much oxidized, cross-bedded; no fossils.

SEC. XIV.—This section appears in part at the top of the hill at Hooser but is better studied west of Grouse creek, two miles northwest of Dexter, Kas., at a cut known locally as "The Sliding Bluffs."

Red and blue shale.

Rather shaly limestone; most fossiliferous stratum found: *Derbya, Productus nebrascensis*, and *Productus semireticulatus, Pinna allarisma, Aviculopecten occidentalis, Myalina permiana, Myalina kansensis*, crinoids, *Athyris subtilita*, lamellibranchs and univalve.

Six feet of massive limestone with flint nodules.

(*a*) Stratum with a very peculiar *non-calcareous* nodular concretion, brown, showing oval rings wherever broken.

Three feet of massive limestone with flint.

(*b*) Six-inch bed of *calcareous* nodular concretions much resembling those in (*a*) but calcareous and smaller.

Massive limestone; common fossils.

SEC. XV.—Five feet red clay.

Rotten shaly limestone; fossiliferous.

Massive limestone.

Rotten limestone.

Massive light-gray limestone with flint nodules; *upper flint beds.*

SEC. XVI.—Thin-bedded hard blue and gray limestone, very

persistent; barren. The commercial building stone of Cowley county.

Gray shale.

Massive limestone.

Shale at surface near Eaton, Kas.

The 14-foot layer at the bottom of section XVI can be traced across the country to Winfield. It supplies the building material for Winfield and is extensively quarried at different points in the county.

Thin-bedded blue and gray limestone exposed in bed of river below dam, same as exposed near Eaton. The building stone.

Unexposed.

Greenish yellow rotten limestone.

Very hard massive limestone.

Shale, greenish yellow oxidizing on exposure to air giving a red color to many slopes in vicinity.

Finely laminated massive limestone with many small nodules (½ to 1 inch) inclosing a crystal as fossil.

Greenish yellow shale, barren.

SEC. XVII.—Rugged massive limestone, very persistent, forming cap of many hills and knobs east of the Walnut; not laminated but very fossiliferous: crinoid stems, Pinna aechaeacidale, Bryozoa, corals. So different from neighboring rock that I make it a section.

SEC. XVIII.—Blue shaly limestone, fossiliferous; Productus Athyris, Aviculopecten, etc.

Massive limestone; barren.

Fossiliferous shale and limestone.

Unexposed.

Massive limestone.

Unexposed.

Thin-bedded massive limestone quarried at Arkansas City.

Shale to top of hill.

Dakota sandstone.

Tertiary conglomerate.

Section XVIII was made on the east slope of the Walnut at Arkansas City. Some five miles northwest of the city I found several patches of dark-brown sandstone which Professor Hay takes to be Dakota. At the end of the Geuda Springs bridge, five miles northwest of Arkansas City, is a good exposure of Tertiary grit. West of the Arkansas are several exposures of black and blue shale along certain ravines, but I have never tried to estimate the thickness.

CHAPTER II.

A GEOLOGIC SECTION FROM BAXTER SPRINGS TO THE NEBRASKA STATE LINE.

BY ERASMUS HAWORTH AND JOHN BENNETT.*

The Mississippian Limestone.
The Cherokee Shales.
The Oswego Limestones.
The Pawnee Limestone.
The Pleasanton Shales.
The Erie Limestone.
The Iola Limestone.
The Lane Shales.
The Garnett Limestone.
The Kansas City Section.
Section at Soldiers' Home. Fig. 4.
Section at Atchison. Fig. 5.
Section three miles above Doniphan station and two miles south of Brenner station. Fig. 6.
Over the Divide.
Section at Iowa Point and along on the bluff east of it. Fig. 7.

THE MISSISSIPPIAN LIMESTONE.

Baxter Springs rests upon the Mississippian, or Sub-Carboniferous ore-bearing series. This series is of undetermined thickness. Jenney† has estimated it at about 300 feet. A deep well at Girard penetrated to a depth of 350 feet and seems not to have gone through it; one at Cherryvale penetrated it to a depth of 220 feet without going through it; the artesian well at Fort Scott went nearly 250 feet into it apparently without going through it. An accurate record of the deep well at Paola has not been published and perhaps never can be obtained in reliable form. The well represented in the drawings for this section, plate II, entered the Mississippian only about 20 feet, and the one at Kansas City a less distance. Five wells have been drilled at Pittsburgh, each of which perhaps passed entirely through the Mississippian formation, but no careful record

*The first part of the chapter to Kansas City is by Professor Haworth, the remainder by Mr. Bennett.

†Lead and zinc deposits of the Mississippi valley. Trans. Am. Inst. Mining Eng., 1893, p. 55.

was kept of any of them so that they throw no light upon the subject. The record of the deep well at Leavenworth shows no cherty limestone which to the south characterizes this series, but in its stead gives 300 feet of "hard white sandstone." This "sandstone" possibly is a cherty limestone. The suggestion is made because the cherty limestone is known to exist at Kansas City, and continuously from there to the south line of the state. One can hardly realize how so persistent a characteristic would change so abruptly. Further, at the great depth at which the "sandstone" was reached it would be a comparatively easy matter for the driller to mistake the chert grains produced by the "churn drill" for grains of sand. This thought is strengthened by the fact that the Mississippian series is preeminently a limestone series wherever known throughout the whole Mississippi valley. If the well record is in error as indicated we should consider the limestone series 300 feet thick at Leavenworth.

The upper surface of the Mississippian was greatly eroded during pre Coal Measure time, as has already been shown in chapter I in the description of the section along the south line of the state. The surface dips gradually to the north, as is plainly shown in plate II, which was drawn to an exact scale, the information being gathered mainly from the records of the deep wells along the lines. The outline map, plate XXXI, shows that this section trends only slightly diagonally to the boundary line between the Mississippian and the Coal Measures, and therefore the dip would not be nearly so great as in directions at right angles with the boundary. As it is we have a dip of 333 feet from Baxter Springs to Girard, a distance of 35 miles, or 9.5 feet to the mile; a dip of 433 feet to Fort Scott, 62 miles, which gives 7 feet to the mile; a dip of 635 feet to Pleasanton, 87 miles, or 7.3 feet to the mile; a dip of 975 feet to Paola, or 9 feet to the mile; and one of but 800 feet to Kansas City, or 5 feet to the mile. It will thus be seen that the upper surface of the Mississippian has great irregularities which cannot be attributed to surface erosion, but rather to great undulations which are essential properties of the whole system. The great synclinal at Paola corresponds exactly with the position of the higher limestones, although the Cherokee shales are so thickened here that it would

seem there can be no relation between the Mississippian limestones and those above the shales. From Kansas City to Leavenworth the direction is changed to one almost at right angles with the boundary between the Coal Measures and the Mississippian, so that we would expect to have almost the maximum dip. In a distance of 22 miles there is a dip of 390 feet, or 18.2 feet to the mile, which is nearly equal to the westerly dip of the surface of the same series from Galena to Cherryvale, which has been shown to be about 21 feet to the mile.

THE CHEROKEE SHALES.

Immediately above the Mississippian are the Cherokee shales and sandstones, the lowermost portion of the Coal Measures. Less than a mile to the west of Baxter Springs is a series of sandstone covered hills from 50 to 75 feet high, the main body of which is principally shale, but which here and there has considerable sandstone interbedded with it. Such hills are irregular in their position, indicating a lack of regularity in the protecting sandstone covering. One circular hill about six miles to the west is particularly prominent, as it is entirely surrounded by a broad valley of erosion with the hill nearly 150 feet high standing alone in the center. The sandstone on the summit of this hill may or may not be the equivalent of that nearer Baxter Springs. Passing northward towards Columbus the sandstone and shale alternate with such frequency that one is entirely unable to trace the former any considerable distance. That near Baxter Springs may with question be correlated with the sandstone on top of the hills east of Columbus, and on which Columbus rests. The section from Baxter Springs to Columbus, if represented in great detail, would well illustrate the utter futility of using sandstones within the Cherokee shales as important stratigraphic factors; for not even one of them below the Columbus sandstones, numerous as they are, can be traced very far until it gradually changes into arenaceous shales, and finally into shales of the ordinary type.

At the altitude of Columbus, or about 200 feet above the Mississippian, we find a heavy sandstone deposit which is tolerably persistent towards the east for seven or eight miles, forming the uppermost portion of the highlands and hills to the east, almost to Crest-

line, a station eight miles east of Columbus on the St. Louis & San Francisco railway. This system of hills is well represented in the section along the south line of the state, plate I, as are also the various coals occurring in the Cherokee shales below the Columbus sandstones.

Passing northward from Columbus nothing of special interest is found until the Weir City-Pittsburgh coal is reached, about four miles north of Columbus. The roofing for the coal is shale, so that no topographic features mark the outcropping, and the weathering has produced so heavy a soil covering that the outcropping can only occasionally be seen. This coal is the heaviest and most important of any in the state. Its southeastern limit is a sinuous line trending northeast to southwest approximately parallel to the boundary between the Coal Measures and Mississippian. In the early days of mining the stripping process was principally employed. This located a number of mining villages along the line of outcropping, which, in turn, attracted the different railroads. Both these causes, in connection with the desirability of shallow shafts when shafting became necessary in the mining operation, have contributed to building the principal mining towns along this northeast and southwest line. The coal extends to the northwest much farther than mining operations have progressed, but the limit of workable coal is soon reached, as is shown by the well at Girard and many other prospecting drill-holes which have been made from time to time. The belt of workable coal seems to be a strip from five to ten miles wide reaching from beyond Mulberry on the northeast almost to Hallowell on the southwest. The exact definition of the area can only be determined by the most extensive prospecting with the drill, or by shafting, a process so expensive that this Survey could not begin it. Such prospecting has been done to a considerable extent by the different mining companies and landowners, sufficient to justify the above statement of limitations, but not sufficient for giving details along the borders.

The coal averages about 40 inches thick where mined, but over considerable areas within the mining district it is only from 24 to 36 inches in thickness, while in other places it considerably exceeds 40 inches. On the whole it is a remarkably uniform coal

deposit, both in thickness and quality. Few coal beds are known in America with equal areal extent which are as uniform in qualiity and quantity as this.

The coal beds dip to the west and northwest, quite irregularly over small areas, but approximating the dip of the surface of the Mississippian for long distances. In some places the dip for a short distance is as great as three or four degrees, or 275 to 365 feet to the mile. But such steep inclinations are usually followed by lesser ones, or by actual reversals, so that the general average is brought down to about 20 to 21 feet to the mile.

The mining operations have revealed an important condition which perhaps is always concealed from view at the surface, namely, the slight fissuring and faulting of the strata. The so-called "horse-backs" of the miner are variable in character. One type consists of a fissure formed in the coal and shales, both above and below, long after the coal was formed, which has since been filled with clay from the walls of the fissure in the overlying shales, or by the "creeping" of the clay beneath. Such fissures have been formed from one to five or more feet wide, either with or without vertical displacement. When displacements occur they usually are from 6 to 12 inches, but occasionally reach two or three feet. In some cases small fragments of coal have been found imbedded within the clay filling, as though it had fallen in during the filling process. Also the line of fracture is rarely straight through the coal, but the irregularities on one side generally correspond quite well with those on the other. Many of the fissures are only partially filled with the clay. One was noticed at Weir City which extended unfilled upwards into the roof for 10 or 15 feet, as could plainly be seen while standing in the driveway of the mine. There can, therefore, be no doubt but that the fissuring and faulting was done long after the solidification of the coal, possibly during the period of the production of similar fissures and faults in the lead and zinc mining districts to the southeast.*

The Cherokee shales have a few thin, irregular limestone beds within them. Only one of them has sufficient thickness or lateral

*Jenney: Lead and zinc deposits of the Mississippi valley, Trans. Am. Inst. Mining Eng., 1893, p. 55.

extent, as developed at the surface, to be of any importance stratigraphically. This one lies 75 feet below the upper limits of the shales, and is from two to five feet thick. According to the reports obtained from Mr. W. E. Turkington, of Cherokee, Kas., a gentleman of wide experience in prospecting with the diamond drill, it is varied in its occurrence. He reports that in many wells, especially those to the northwest, it is not found. At Oswego it is about three feet thick. It is visible in a number of different places to the northeast of Oswego, is plainly to be seen in a ravine half a mile to the west of Cherokee, and should be about 20 feet under the surface in the town. But Mr. Turkington reports that it is not, nor is it met with to the south, as he has determined by many drilled wells. In the drawing, plate II, it is represented as first appearing to the south of Cherokee. This was done in order to place it at the proper height vertically. In the vicinity of Fort Scott two or more small limestone formations occur near the same vertical position, but there is great uncertainty about correlating it with either of them; for it may well be questioned whether so thin a limestone system would have so great a lateral extent. Yet it should be noticed that in the other wells to the north, even as far as Kansas City, more or less limestone is found at about the same geological horizon, indicating that at this particular period more or less limestone was formed almost all over the Coal Measure area.

The total thickness of the Cherokee shales along the east line of the state may be given at 450 feet, although they are not entirely uniform. At Girard the drill record shows them to be 446 feet; at Fort Scott they are a little less than 425 feet; at Pleasanton they are full 440 feet; at Paola they have thickened to nearly 750 feet, if we may credit the record of the city well, the most reliable of any record available; at Olathe their thickness is unknown. The well represented in plate II evidently did not reach the Cherokee shales at all. At Kansas City they have a thickness of 420 feet, and at Leavenworth they are full 540 feet.

THE OSWEGO LIMESTONES.

First above the Cherokee shales lie two limestone systems so close together that they may well count as one. They occur prom-

inently at Oswego, and have been called the Oswego limestone. From Oswego their outcropping extends northeast, passing about two miles north of Cherokee, half way between Girard and Pittsburgh, and capping the high hills between Pittsburgh and Englevale, from which they pass to beyond the state line. To the northwest of the line of outcropping they cover nearly all the surface for a distance of 8 or 10 miles, the highest hills only being capped with a limestone occupying a higher position, while the lowest valleys may lie partially or wholly within the Cherokee shales. In this way they extend northward to Fulton, beyond which they pass below the surface to be seen no more along the line of this section. The character of the Oswego limestone as seen in the environs of Oswego has already been given by Adams in chapter I of this Report. They maintain this character with wonderful persistency in all directions. At Girard the lower one is 18 feet thick and the upper one 14 feet thick, and are separated by only four feet of black bituminous shale. At Fort Scott they are exposed over several square miles of surface. Here the lower one is a little over five feet thick and constitutes the "cement" rock from which the Fort Scott hydraulic cement is so extensively manufactured. Above the "cement" rock the shale is seven feet thick, and includes a thin seam of coal of three or four inches in thickness. Above this comes the upper Oswego system which is 10 feet thick. Immediately below the cement rock the shale is likewise very black and bituminous for a distance of 11 feet, immediately below which is the Fort Scott "red" coal with an average of about 13 or 14 inches in thickness at this place. The Oswego limestones are therefore associated with the two beds of jet-black shale, the one below and the other between the two. These shales have such marked characteristics that they are of great assistance in recognizing the limestone series. They also have great lateral extent, reaching all the way from Girard to Fulton without any perceptible change in their characteristics. Mr. Bennett has described them in considerable detail along with the Fort Scott coal and the two limestone systems as they occur at Fort Scott in his description of a section from Fort Scott to Yates Center given in chapter IV of this Report.

Regarding the terms by which these limestones should be desig-

nated it may be said that although the name "Oswego" limestones has been used it would be equally convenient to call them the Fort Scott limestone. Should one choose to use the latter term rather than the former, one should be careful not to include the upper limestone, a heavy system which is well developed around Fort Scott, capping the hills on all sides.

The Oswego limestones, although perfectly conformable with each other are rarely found in an exact horizontal position. A glance at plate II will show this better than it can be described by words. There is a great anticlinal ridge between Pittsburgh and Fort Scott with its axis trending about south 70 degrees east. In extreme cases the limestone dips either north or south two degrees or more. South of Englevale about a mile they dip north fully 150 feet to the mile for a distance of half a mile, beyond which on either side the inclination is greatly reduced. Another similar instance was noticed on the south side of the ridge about four miles east of Girard. Here along the headwaters of one branch of Cow creek an exposure was found where the limestone dipped southerly at the rate of over 100 feet to the mile. It is probable the southeast dip of the limestone is the principal cause for the absence of a marked escarpment at the border or outcropping of the limestone. At Fort Scott the rocks are dipping north, but three miles north, just beyond the cement factory, they begin rising to the north at a sharp angle. This is plainly noticed along the railroad, for the roadbed rests directly upon the upper limestone for nearly a mile, throughout the whole of which distance there is a relatively heavy grade.

First above the Oswego limestone is a bed of shales, arenaceous in places, which varies in thickness along this line from 25 to 40 feet. At Fort Scott it measures nearly 40 feet, while five miles to the north it is not more than 25 feet thick. In a few places it assumes a jet-black color and contains many small concretions with small fossil shells serving as nuclei, just as those between the Oswego limestones. This is particularly noticeable at Prescott. The well and pool by the old mill have passed through the limestone, which was quite thick here, and have revealed the black shale filled with concretions. One might easily be misled here, for it would be natural to mistake this limestone with the associated shales for the Oswego

limestone. Coal is also found in these shales in some localities, but only in small quantities, and therefore not of sufficient extent to be of any commercial importance.

THE PAWNEE LIMESTONE.

Above the shales just mentioned is a tolerably heavy limesone system which is first observed along this section a little south of Farlington. Its exact limits could not be located along the railroad, but only a few miles north of Girard to the east and west of the railroad prominent escarpments locate its limits exactly. At Farlington it is very prominent, and is easily traced all the way to beyond Fort Scott. In character it is massive rather than laminated. Along the hilltops it weathers into large blocks rather than small fragments. Its thickness is difficult to estimate on account of its being worn to a thin edge, but it reaches 15 feet in some places. According to Mr. Bennett, in chapter IV, a few miles to the west of Fort Scott it thickens to fully 30 feet.

This limestone has been named the Pawnee limestone by Swallow* on account of its great development around Pawnee, a station on the Missouri Pacific railroad to the south of Fort Scott. As the name was well chosen, and corresponds with the method adopted by this Survey of giving local geographic names to the different geologic horizons, it will be adopted here. In the vicinity of Fort Scott the Pawnee limestone caps all the hills. Passing northward to Prescott it can be seen on hills all the way on either side of the Memphis railroad. At places the track rounds a hill point with the limestone only a few rods away, while beyond the valley may widen to miles each side of the track. About five miles to the north of Fort Scott the limestone comes down to within 25 feet of the Oswego limestone, but beyond it rises slightly to a height of 40 feet or more. Just south of Hammond, a small, flat-topped, circular mound, capped with the Pawnee limestone, is a prominent feature in the landscape, while to the southeast and to the northwest rows of hills of some height are capped with the same rock. At Prescott it lies at the surface, while farther north it passes underground and is seen no more, excepting in the shafts below the coal at Pleasanton

*Swallow: Prel. Rep. Kansas Geol. Survey, p. 24; Lawrence, 1866.

and Boicourt, and in the records of the drilled wells at Pleasanton, Paola, and other points to the north.

THE PLEASANTON SHALES.

Above the Pawnee limestone lies a heavy bed of shale which is of great stratigraphic importance. It contains within it one or more small limestone systems of little importance. Such an one is the limestone northeast of Pleasanton along the branch, the eight-foot one mentioned by Bennett on the Fort Scott-Yates Center section, and the one near the surface just above the Mound City coal, which seems to be the same as the one northeast of Pleasanton. On account of the heavy development of these shales at and around Pleasanton it is proposed to call them the Pleasanton shales. They have been an important factor in producing the topography so characteristic of the zone reaching from La Cygne away to the southwest to beyond the Neosho river, and in fact by way of Cherryvale and Mound Valley to the south line of the state. Could one stand on a high prominence near Fort Scott and use a proper telescope he could observe a chain of hills and bluffs throughout this whole distance. Beyond the Neosho river the row becomes divided into two or more branches, but nearer Pleasanton they are united into one. The Pleasanton shales constitute the great bulk of these hills and the limestones above cap them and protect them from erosion. The thickness of the Pleasanton shales differs greatly. At Boicourt they are more than 225 feet thick, with an equal thickness to the southwest; but to the north they rapidly become thinner as far as Paola, beyond which they again thicken to nearly 200 feet at Kansas City.

In places the Pleasanton shales carry large quantities of sandstone, sometimes in broad, even, thin layers, producing the best of flagging stone, sometimes in more massive form. Excellent examples of the former are found near Bandera and Gilfillen west of Fort Scott, the quarries of which produce what is known in the market as the Fort Scott flags. Near Farlington is another place where flagging stone of excellent quality are extensively quarried from beds contained within the Pleasanton shales. Other examples also might be mentioned, particularly the flagging stone

west of the Neosho river quarried so extensively by Mr. Robinett who has introduced them to the city of Parsons and supplies such great quantities for making walks. The massive variety of sandstone is well illustrated at Boicourt by the heavy beds which lie at the very summit of the shales immediately under the next succeeding limestone. Here the layers are four or more feet thick and were once quarried for dimension stone.

The Pleasanton shales are also noted as coal-producers. The Pleasanton coal, the Boicourt coal, the La Cygne coal, and the Mound City coal all come from them. The Pleasanton, Boicourt, and La Cygne coals lie almost at the base of the shale beds, but the Mound City coal is nearly 100 feet higher. To the south of Pleasanton, almost all the way to Fort Scott, coal is mined irregularly every few miles on each side of the railroad. Some of these mines seem to be located below the Pawnee limestone, possibly below the Oswego, in which case they would correspond to the Fort Scott coal. But others of them are higher and may correspond to the Pleasanton coal. As but few of such banks were visited, positive statements regarding them cannot be made.

It has been decided to let the upper surface of the Pleasanton shales be the upper limitation of the lower Coal Measures. The paleontologic evidence favors this, while other considerations are given in chapter IX for locating the division of the Coal Measures at this particular place.

THE ERIE LIMESTONE.

Above the Pleasanton shales a series of limestone systems is met with which consists of five or six systems at La Cygne, a smaller number south at Boicourt, and still smaller at Pleasanton. At the latter place there is but one limestone capping the hill, or possibly two, with almost no shale between. This limestone also forms the top of a long row of hills reaching westward toward Mound City. At Boicourt, the high hill west of the railroad furnishing the following section, beginning at the top of the hill and passing downwards:

No. 1—20 feet limestone.
No. 2—6 feet shale.

No. 3—6 feet limestone.
No. 4—6 feet shale.
No. 5—4 feet limestone.
No. 6—4 feet shale.
No. 7—5 feet limestone.
No. 8—11 feet shale.
No. 9—10 feet sandstone.

No. 10—94 feet shale to road grade. The same shale continues to the bed of the river. From the best information we could gather it seems that the shale continues downward a hundred feet or more, making the total thickness of the Pleasanton shales from 200 to 225 feet. It will thus be seen that four limestone systems are here found. The lower one possesses all the characteristics, both lithologic and paleontologic, of the one at Pleasanton, and unquestionably should be correlated with it. Of those above the first two are thin, with the lower one probably belonging to the bottom one. The fourth one is the most nearly distinct.

The high bluffs and hills north of La Cygne furnish another good section. The limestones are here dipping rapidly to the north. The Memphis railroad cuts through them to obtain a crossing over the Osage river, so that portions of the rocks are laid bare in the cut. The following section is here exposed, the hill on the east side being higher than the one on the west. Beginning at the top of the hill and passing downward we have:

No. 1—25 feet limestone.
No. 2—20 feet shale.
No. 3—20 feet limestone.
No. 4—13 feet shale.
No. 5—4 feet limestone.
No. 6—8 feet shale.
No. 7—3 feet limestone.
No. 8—8 feet shale.
No. 9—2 feet limestone.
No. 10—7 feet shale.
No. 11—7 feet limestone.

No. 12—11 feet of shale to railroad level with river bed 46 feet below.

Here also the lowest limestone system corresponds with the bottom one at Boicourt and Pleasanton, so much so that one need have no hesitation in correlating it with them, although it must dip rapidly from Boicourt to reach its position here.

By comparing these sections with Mr. Bennett's section from Fort Scott to Yates Center and considering topographic features to the southwest, as above outlined, it would seem we are here dealing with the limestones which form the heavy outcropping near Uniontown which has been called the Erie limestone farther to the west. They can be traced northward all the way to Kansas City, at which place the lowermost one corresponds to No. 78 of Broadhead* which he calls the Bethany Falls limestone.

IOLA LIMESTONE.

Here at La Cygne we have another limestone lying above the Erie limestone and which seems to be the Iola limestone. At Iola 100 feet of shale lie between it and the Erie, but here there are scarcely more than 25 feet. Further, instead of having only three systems below there are five close together, as though they were related, but some of them are so thin they may not extend far away. The uppermost rock at La Cygne possesses all the characteristics of the Iola limestone, compact, solid, crystalized almost into a marble, and unusually free from fossils. In order to throw light upon this correlation a journey was made west from La Cygne until the Garnett limestone was reached. By counting southward from this point to Iola and eastward to La Cygne the same conclusion is reached, so the matter may be looked upon as settled that the uppermost limestone system in the vicinity of Mound City, Boicourt and La Cygne is the Iola system. Immediately on the high hill at Boicourt it is not found, but it is reached only a short distance to the west. At the bluff north from the river near La Cygne the same grouping of limestone systems is noticed. Here, however, they dip to the south, or rise to the north towards Fontana. The Osage river is, therefore, following a synclinal valley at this place. The railroad from the bridge near La Cygne gradually climbs the hill occupying four or five miles in making the ascent to Fontana. In many places

*Missouri Geol. Rep., 1872, p. 83.

along the line the grading has laid the hillside sufficiently bare to furnish good sections. It is noted that the massive limestone is plainly visible almost all the way with the lower systems in their proper places relatively. To the south and west of Fontana the Iola limestone appears everywhere at or near the surface, constituting the great mass of limestone so abundant in that vicinity. It gradually dips towards the northwest to Osawatomie and to the north to Paola. Fontana is therefore on the summit of an anticlinal ridge the axis of which trends about north 70 degrees west, gradually dipping below the surface. The Iola limestone lies near the surface all the way to Paola, at which place it covers the lesser hills of the main upland. It is found in a number of places within the city limits, and is the first limestone system below the one covering the highest hilltops in and around Paola. It is here greatly reduced in thickness, not being more than 15 feet thick in most localities. Just how much its original thickness has been reduced by surface erosion cannot well be determined. To the north, towards Olathe, it gradually becomes more prominent. On many of the lesser hills to the east of the Memphis railroad it is very prominent. In some places four or five miles east of Paola it caps prominent, flat-topped mounds and rows of hills. At Hillsdale it is the cap-rock on the hilltop just south of Bull creek, plainly visible near the wagon bridge. It rises all the way from Paola to Olathe, at which place it is so thickened that along the head waters of Cedar creek, from two to four miles west of Olathe, it is full 50 feet thick. From Olathe it passes on to the north and constitutes the heaviest limestone in the bluffs of Kansas City numbered 98 by Broadhead.*

THE LANE SHALES.

Above the Iola limestone along the line of this section a shale bed appears which, in the vicinity of Osawatomie and Paola, is from 75 to 100 feet thick. Along the south bluffs of the Pottawatomie river it is generally about 75 feet thick; between Osawatomie and Paola at one place it measured 95 feet; while in the hills northeast of Paola it is from 75 feet downwards as more northern points are reached. It forms the main mass of hills each side of the Memphis

* Broadhead, *loc. cit.*, p. 107.

railroad from Paloa to Olathe, but it gradually grows thinner, as the Iola limestone rises, until in the vicintiy of Olathe it is less than 25 feet thick. West of Olathe along the bluffs of Cedar creek it seems to thin out so that the Iola limestone and the one above almost come together, and are in places not more than 10 or 15 feet apart. But to the southwest beyond Osawatomie they gradually thicken to much over a hundred feet. They separate the Iola limestone from the limestone system containing the famous quarries at Lane, and the Garnett limestone in and around Garnett, and therefore should be correlated with the great shale bed on which Colony rests, and which furnishes so much sandstone in the vicinity of Neosho Falls, Burlington and Yates Center. The name Lane shales is proposed for this shale bed, on account of their being so well developed at the little town of Lane, a village made somewhat famous in Kansas on account of the extensive quarries near by, and also to emphasize the fact that the Lane "marble" and the Iola "marble" belong to two different limestone systems.

THE GARNETT LIMESTONE.

Beginning at the summit of the highest hills southeast of Paola, an important limestone system is first met along this section which is very prominent to the southwest, and which has already been named the Burlington, or Garnett* limestone. In most places it is recognizable as two distinct systems about 10 or 15 feet apart, but from Paola to Olathe it usually is seen as but one. It caps all of the highest hills between these two places, and for miles around. As has just been shown, it is slightly nonconformable with the Iola limestone, due to the thinning out of the Lane shales to the northeast. Immediately under the town of Olathe it is only 15 feet thick, but a few miles west it thickens to nearly 50 feet. This is the same system which a mile southwest of Greeley thickens so suddenly locally from a few feet to almost 50. From Olathe it dips slightly in almost every direction excepting the east. It reaches Ottawa and beyond to the southwest, where it is in two well-marked systems, and Eudora to the northwest. It is quite possible, in fact probable, that

* Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 110.

around Paola and Olathe it is in two systems with so thin a parting of shale that it has been misinterpreted. Its most noted feature, and the one which will give it the widest reputation, is the fact of its containing the famous "marble" quarries at Lane. From Olathe it passes northward to Kansas City, as is shown in plate II.

The general highlands forming the environs of Paola and the broad plateau of Olathe pass northward unchanged to the bluffs of the Kansas river between Kansas City and Eudora. The different rock systems, then, along the river bluffs are practically the same as those described from Pleasanton northward. The borings at Paola and Olathe confirm this view, as is shown in plate II, which should be referred to constantly while reading this chapter.

THE KANSAS CITY SECTION.*

A comparison between the stratification at Kansas City, as now seen in the bluffs where good exposures are made by natural or artificial means, and the description given by Broadhead† shows that his section is correct in the main excepting near the summit of the bluffs, where good exposures did not exist at the time his report was prepared. The complete section is as follows, beginning at the top, which is almost identical with the Argentine section, figure 2:

Section at Kansas City.

1st.—6 to 10 feet arenaceous limestone.

2d.—6 feet sandy shale, which reaches to Broadhead's section.

3d.—30 feet gray, bluish gray and flesh-colored limestone, the Iola limestone.

4th.—25 feet blue and olive-colored shales.

5th.—5 feet heavy-bedded limestone.

6th.—Thin seam of clay, 4 inches.

7th.—15 inches blue limestone.

8th.—2 feet bituminous and blue clay shales.

9th.—18 inches in one bed of limestone.

10th.—16 inches blue clay shales.

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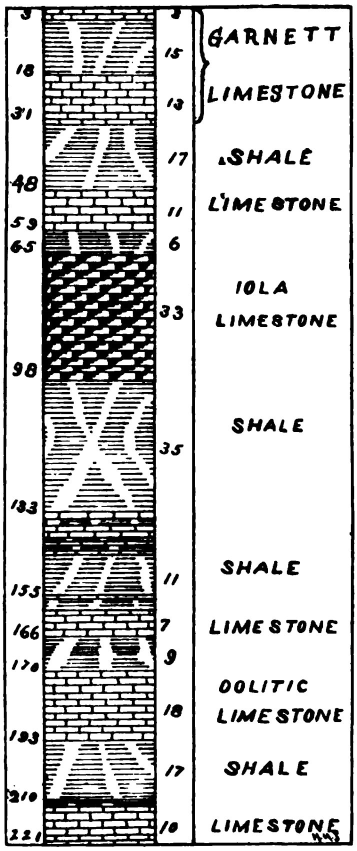
*The remainder of this chapter is by Mr. Bennett.
†Broadhead: Missouri Geol. Rep., part 2, p. 107, 1872.

Figure 2. Kans. Univ. Geol. Surv.

ARGENTINE SECTION



11th.—16 inches blue limestone largely composed of comminuted shells.

12th.—11 feet: 5 feet 8 inches blue clay shales and 5 feet 4 inches buff and drab nodular shales.

13th.—9 feet fine-grained, greenish gray, even-bedded limestone.

14th.—7 feet clay shales.

15th.—3 feet irregularly-bedded limestone.

16th.—18 feet oolitic and gray limestone.

17th.—13 feet shale.

18th.—1 foot agrillaceous limestone made of comminuted shells.

19th.—10 inches drab clay shales.

20th.—5 inches argillaceous limestone.

21st.—2 feet drab clay shales; 6 inches buff shales, and 6 inches blue shales.

22d.—1 foot argillaceous limestone.

23d.—1 foot buff and 3 feet of blue shales.

24th.—12 feet deep-blue limestone and black chert in the upper 4 feet. From this down it is an argillaceous limestone and blue in lower strata.

25th.—4 feet blue clay shale.

26th.—7½ feet heavy limestone, in two layers.

27th.—10 inches blue shale.

28th.—5 feet even-bedded limestone.

29th.—2 inches of clay.

30th.—3 inches limestone.

31st.—3 inches buff shale.

32d.—1 foot buff clay rock.

33d.—10 inches yellow ochre shale.

34th.—2 feet drab shale.

35th.—1½ feet bituminous shale.

36th.—3 feet clay shale.

37th.—2 feet nodular buff shale.

38th.—18 to 20 feet heavy-bedded limestone (Bethany Falls of Broadhead).

39th.—5 feet drab, blue and bituminous shales.

40th.—1½ feet even-bedded limestone.

Making a total of about 225 feet.

In the above section it can be seen that there are at least eight limestone systems some of which have been correlated with those described in previous chapters. In the descending order they are as follows:

1st.—The arenaceous limestone—10 feet.

2d.—The Iola limestone, top rock of Broadhead and heaviest bed—30 feet.

3d.—Large fossil and heavy-bedded limestone—5 feet.

4th.—Fine-grained building-rock—9 feet.

5th.—Oolitic limestone—21 feet.

6th.—Black, cherty limestone—12 feet.

7th.—Heavy-bedded and clay parted limestone—12½ feet.

8th.—Bethany Falls of Broadhead—20 feet.

These are persistent systems and we will have occasion to speak of them again in the Kansas river section, Chapter VI of this Report. It will be seen that they represent fully 119 feet of the section, and that the separating shales, etc., sum up 106 feet of which 94.6 feet are clay and bituminous shales, and 12 feet thin limestone layers, giving a preponderance to the limestone, all told, of 35 feet in the entire 226 feet of the section. Before going further a brief description of the fossils found in these systems might be of interest.

The arenaceous or uppermost system has a few of the common Coal Measures species—*Athyris subtilita* being plentiful.

The Iola limestone, or top rock, yields some well preserved fossils, such as *Spirifer cameratus; Spiriferina kentuckiensis; Productus longispinus; Productus costatus; Productus punctatus; Productus nebrascensis; Terebratula bovidens; Athyris subtilita; Myalina swallovi;* Bryozoans, and others.

In the large fossil heavy-bedded system which comes next two species of the Productidae, *punctatus* and *costatus* are very large and numerous in certain localities. In a thin clay seam not far from the base of this system lies the rare little *Conularia crustula,* and the bituminous shales below have many bruised specimens of the characteristic Coal Measure fossil *Pleurotomaria sphaerulata.*

The fine-grained limestone which comes next in many places can be distinguished by its abundance of *Campophyllum torquium.*

It also has *Lophophyllum proliferum; Fistulipora nodulifera* and several species of the Brachiopoda.

Next in descending order comes that wonderful Oolitic bed, useful in building and noted for its many well preserved fossils. Representatives of the seven sub-kingdoms of the animal kingdom are found in it. The Protozoans by Fusulina, the Coelenterata by its tabulate and rugose forms, the Echinodermata by Echinoidea and Crinoidea, the Mollusca by many species of the Polyzoa, Brachipoda, Lamellibranchiata, Gasteropoda, Pteropoda and Cephalopoda, the Arthropoda by the Trilobita, and the Vertebrata by fish teeth. Over 70 species in all have come under our notice from this one system.

Below the Oolite limestone is the black chert system which has in it numerous rare and well preserved fossils. Many of the Gasteropoda in this rock have been silicified instead of remaining calcified as is common in limestones. In a bluish-gray layer immediately below the one in which the chert predominates fine specimens of *Nautilus ponderosus* exist. Just above it and forming part of it seem to be remains of plants, such as cordiates, and to these are attached the genus *Spirorbis.* There are also associated with these specimens which seem to be charred wood, all of which give evidence of an estuary in the great western sea which then lay outside of the continent, and from which continent the streams descended towards the west. In this deposit many specimens of the genera *Naticopsis, Loxonema* and *Turritella* are found. Among the Lamellibranchiata, *Allorisma subcuniata* and others are represented. Of the Trilobita, *Phillipsia major* has been taken fróm this stratum. It also contains an Orthocerata.

The two remaining systems are not so rich in fossils, and those present are the common species of the region.*

Continuing the section from Kansas City along on the eastern border of the state, and up the Missouri river, and going from the old water-works in Kansas City, Mo., along the bluff to the Hannibal railroad bridge, the first thing noticeable is the dip to the north. The same dip is observable from Argentine to Quindaro, yet the last

* For a further description of the Kansas City rocks the reader is referred to the Kansas river section, chapter VI of this Report.

mentioned line is on the axis of a very perceptible anticlinal, as is shown in plate II.

At the mouth of the Kansas river in Wyandotte the black cherty limestone is found but little above the water's edge; but in the northwestern part of the city this rock is seen considerably above the bed of Jersey creek, while at Quindaro, four miles up the Missouri river, its position is at least 10 feet higher above the water than at the west end of the iron bridge at the mouth of the Kansas river. This same cherty limestone is high above the water of the Kansas river in the Muncie bluffs, three miles west of the Missouri line. All the other limestone and shale systems above this are found in proper position, both at Wyandotte and Quindaro.

Along the Missouri river, above Kansas City, little can be seen of the first limestone above the Iola limestone, as it appears at Kansas City, and which is separated from the latter by six feet of shale at Argentine and Edwardsville.

The fossils of the rocks of the above sections are the same as found elsewhere in them (see chapter XV on paleontology). We must not forget to note, however, that some of the finest and most perfect of the *Pinnidae* were taken from the bed of Jersey creek, in the neighborhood of Thirteenth street in Wyandotte, from the first strata that underlie the black cherty limestone. *Pinna peracuta* a foot long were found here in 1889, when this limestone was being quarried for the foundations of residences that were going up in that neighborhood then.

In a creek east of Quindaro, but heading up towards that village, all of the limestone systems, except the lower beds of Kansas City, Mo., are to be seen, and in their relative positions. The upper, or 20-feet stratum, has been quarried very extensively here in years gone by. Where this creek passes under the Missouri Pacific railway the black chert rock is in places just above the railroad track.

A little above Newman station the gray limestone (No. 4 of our Kansas City section) and its associated thin beds, both above and below it, have been here exposed in a quarry. At this place it has retained its usual thickness of eight or nine feet, and all its lithologic and paleontologic characteristics. Its almost peculiar fossil—

Campophyllum torquium—was here, but not in great abundance as elsewhere in this limestone.

At a small creek to the west of this a short distance, and about two miles east of Pomeroy, all the beds from the Iola limestone of Kansas City down through the gray limestone have been exposed very nicely by the creek erosions. This spot of ground in the native forest is quite romantic. Just above the railroad bridge a wagon road bridge spans the creek, and in the section, as given below, from this bridge to the top of the hill two beautiful little waterfalls occur in the course of the short stream. The upper and larger of the two occurs in connection with the Iola limestone, over which the water falls into a large amphitheater-like basin, formed by the excavations of the shales which underlie it. The creek is dry except after a freshet. This entire fall is over 50 feet. The second fall is much smaller, and occurs in connection with the limestone immediately below the heavy fossil rock of the Kansas City section (No. 96 of Broadhead).

The buff and green shales of the 13-foot stratum in the above section has small calcareous nodules imbedded in them.

The foot of limestone below the two feet of bituminous shales, etc., is immediately overlaid by many fossils, *Productus prattenianus* and *Bryozoans* abound. The oolitic stratum is here decidedly brecciated and corresponds with the cement rock of southwest Wyandotte in many ways, being the equivalent without doubt. This system, which is beautifully oolitic in places, assumes in other places an argillaceous character.

Near this point there is a very fine spring far up in the side of the bluff which supplies the tank, known as Barker's on the Missouri Pacific railway. The water seems to be in connection with the Iola limestone.

At Pomeroy, two miles beyond this, and 10 miles from Kansas City, Kas., some quarrying has been done. Here, for the first time in ascending the river, we have an exposure of the Garnett limestone systems. One of them, and that the lower almost without doubt, showing 20 feet. It is only seen in the hilltops about Pomeroy, for to the west it is cut off by erosion, until Connor is reached. Just above the 26 feet of limestone, in the above section,

in the clay shales, are found many plates of ***Eupachycrinus tuberculatus***, and it is the only place, so far as known, that the ***Coelenterate, Michilinia eugeneae,*** has been found. In the lower part of these shales are also found ***Zeacrinus mucrospinus, Zeacrinus acanthophorus, Lophophyllum proliferum,*** and ***Spirifer cameratus.***

Before reaching Connor, 2½ miles farther up the river, the Iola limestone is seen just above the railroad bridge, and at Connor station it disappears below the valley soils. A small cropping of the Garnett limestone is seen here in the top of the hills, some 85 feet to the summit above the railroad bridge. And just above it is a foot or so of shale, which in turn is overlaid by a thin stratum of limestone.

Above Connor, one mile, there is a small exposure of the limestone, the top of which can only be seen, and is eight feet higher than the railroad grade. This is perhaps our No. 1 of Kansas City—Broadhead's No. 100 (?)—which is not a persistent limestone. At the top of the hill in Kansas City, Mo., it is found 8 to 10 feet thick, and is separated from our No. 2 by six feet of clay shales. At Argentine it is a siliceous limestone 11 feet 3 inches thick and six feet above No. 2 as at Kansas City. At Edwardsville, 12 miles up the river on the north side, it retains this thickness and lithologic characteristics, and is separated from the underlying limestone by the same thickness of shale as at Argentine. So far as our observation extended, it was not seen around Kansas City, Kas., or Quindaro. Up the river, towards Pomeroy, the hills are high enough to contain it, but it was not seen. At Pomeroy the thin layer observable above, our No. 2, was too high for it. The lower rock as seen exposed, in section one mile above Connor, would be in about position for it, but does not partake of its siliceous nature. At Ross the siliceous or semi-oolitic limestone would seem to be its equivalent; but the position of the rock here is evidently too high. In giving the sections at Kansas City, Broadhead evidently overlooked it altogether, unless it is his No. 100, which stratum varies greatly according to his report.* One mile above Connor there is a thin oolitic ledge 56 feet above the railroad bridge which contains many fossils of Myalina subquadrata, a fossil found in the semi-oolitic of

* Missouri Geolog. Surv., 1872, part II, p. 107.

Ross, but not so much in the limestone itself as in a clay streak immediately above it. The Oolite of the Connor section also carries *Loxonema* ———, *Phillipsia major, Aviculopecten occidentalis, Productus nebrascensis, Spirifer cameratus, Edmondia* ———, *Monoptera* ———, etc.

Proceeding up the river to Ross station there is a small exposure which was recently made, the railroad company having cut into the side of the bluff in order to get their tracks away from the encroachments of the river. Here a siliceous and somewhat oolitic stratum is close by the track. From the ditch up six feet of it is seen, and above it is six inches of clay in which there were numerous well preserved *Myalina subquadrata,* approaching the type *kansensis,* and *Myalina recurvirostris.* Above this clay was one foot of limestone. All of the limestones contained well preserved fossils, in addition, of the following types: *Bellerophon crassus, Macrocheilus* ———, *Loxonema* ———, and *Polyphenopsis* ———.

Two miles above this, at the rock crusher, the Garnett limestone of the Pomeroy section comes down within 20 feet of the railroad track. Here it is but 14 feet thick, and is separated by a 20-foot slope from another system above 13 feet thick, from which large quantities of stone have been crushed for railroad ballast. Both of these systems are somewhat barren of fossils.

One mile farther on, at the penitentiary pump-house, the upper one of these two systems is eroded away and the lower one thickens here to 16.5 feet and is but eight feet above the railroad track, which distance is occupied by drab clay shales.

Farther on, at Leavenworth Junction, this lower limestone is just above the track.

Going on up to the Soldiers' Home, and passing up the roadway from the station towards the buildings on the top of the hill, the little creek and a quarry or two which have been opened help to fix the location of the limestone. On the top of the hill is a ferruginous brecciated limestone 2.5 feet thick which has been quarried somewhat. Then descending there is a slope of 58 feet 8 inches from the top of this limestone to the top of the upper of the two systems seen at the crusher farther down the river. The upper system has been somewhat extensively quarried here, and is from 11 to 13 feet thick.

Next below it, and separated by five feet of brown, dark and bituminous shales, lies an even-bedded—sometimes in one, again in two layers—drab limestone, which has been quarried here. In the clays immediately below this there is an abundance of *Derbya (Hemipronites) crassus,* in good preservation. Below this is a 10-foot slope before the top of the second limestone is reached. The top of this latter system only is seen here and but 14 feet above the railroad track at the depot.

The upper of these two limestone systems here contains *Spirifer lineatus, Athyris subtilita, Archaeocidaris* spines, *Productus pratteni-anus,* and *Fusulina cylendrica.* The thin, even-bedded layer contains *Pinna* ———, *Chaenomya leavenworthensis,* and *Myalina subquadrata.* Brick clays are also found in this neighborhood from which brick has been made for the buildings in the Home. There are fine springs here in connection with both limestone systems

SECTION AT SOLDIERS' HOME.

Between the Soldiers' Home and Leavenworth the upper Garnett limestone lies in a bold cliff above the railroad track, and frequently the even-bedded layer below it comes into view.

About half a mile down the river from the union depot in Leavenworth a good section of this rock with its accompanying thin layers above and below is to be seen as follows. Beginning at the top there is:

1.—Arenaceous limestone, 1 foot five inches.
2.—Drab shales, 11 inches.
3.—Limestone.
4.—Clay parting. } 1 foot 2 inches.
5.—Limestone.
6.—Argillaceous limestone, 2 feet.
7.—Gray limestone, 12 feet.
8.—Dark bituminous and clay shales, 4 feet 6 inches.
9.—Fucoidal and fossiliferous limestone, 2 feet.
10.—Slope, 4 feet to railroad grade.

In comparing the above section with Meek and Hayden's section at Leavenworth landing, made in the summer of 1858,* there is a

*Pro. Acad. Nat. Sci., Philadelphia, vol. 11, p. 8.

very strong agreement, even to the locating of the fossil ***Derbya (Orthisina) crassa***, found so abundantly in the thin limestone first below the upper Garnett rock. Other fossils mentioned by Meek and Hayden were also found.

Swallow gives a general section of the rocks of eastern Kansas,* and in what he calls the "well-rock series," mention is made of those occurring at Leavenworth, but evidently when he places coals—No. 176 of his section—which are found in the Lawrence shales, below the Garnett limestone, he considers the Oread and Garnett as equivalent, which we now know, by closer observation than he could give them, are not. The Oread limestones are above and the Garnett limestones below the Lawrence shales. According to the correlation of this Survey, the heavy limestone near the base of the hills at Leavenworth corresponds to the Garnett and these on the hilltops at the Reservation to the Oread limestone. Between them, however, are two, if not more, thin limestone systems, one of which at least occurs in the Lawrence shales, in the vicinity of Lawrence. They seem to thicken northward, so that they are very much heavier around Leavenworth.

From the union depot northward in Leavenworth to a creek on the south end of Military Reservation, two miles away, the railroad track lies on a bench formed by the upper Garnett limestone. The last seen of this limestone, before it dips below the river, is on this creek, and the west abutment of the Rock Island railroad bridge which spans the Missouri river here, is built upon it. Above it along the bench already spoken of, between the union depot and the south end of the reservation, are heavy beds of arenaceous shales with many thin, broken layers of sandstone dipping in all directions in them, but mainly dipping where exposed to the south.

At the west end of the Rock Island bridge along that road is a cut exposing the ferruginous brecciated limestone, first seen at the Soliders' Home, which is here largely made up of communited shells. This rock is about six feet thick and crops out all along the bluff for a short distance towards the south and west and for a mile and a half to the north, on the Reservation, except where a small creek cuts it off for a short distance. It has been quarried extensively

* Prel. Rep. Kansas Geol. Survey, pp. 9-29; Lawrence, 1866.

along the outcropping edges for the heavy walls of the military prison.

The fossils of the above brecciated limestone are *Chonetes verneuiliana, Orthis carbonaria, Productus longispinus, Lophophyllum proliferum*, and *Crinoid* columns.

The section at the quarry worked by military prisoners, about a mile and a half above the Fort, shows this ferruginous rock to be 10 feet thick; and in addition to the above fossils of it and its associated shales and thin limestones, some distance above it, there are the following: *Athyris subtilita, Spirifer plano-convexus, Derbya crassus, Euomphalus rugosus, Productus nebrascensis, Productus pertenuis*, a small *Pleurotomaria* ———, *Loxonema* (?) ———, *Phillipsia scitula, Rhombopora lepidodendroides, Retzia mormoni, Myalina recurvirostris, Spiriferina kentuckiensis, Astartella* ———, *Pleurotomaria sphaerulata*, etc.

Two miles up the bluff from Fort Leavenworth there is found at about 42 feet above the railroad tracks a limestone some eight feet thick, which is to be seen all along the bluff in tumbled-down masses. Yet after being cut off by Salt creek a little farther along it was not again to be found in the bluff north of Kickapoo. The brecciated limestone of Fort Leavenworth section is, however, seen along and just above the railroad track until Kickapoo station is reached, where it becomes the foundation for the depot building; and two miles above Kickapoo it finally disappears beneath the valley.

Two miles above Kickapoo measurements were taken up a small creek, at the point where the brecciated limestone was last seen at the valley level, until a height of 227 feet was reached, and here the top of a heavy ledge came in sight. The water in the little creek has cut in many places to the shales, *in situ.*, and in two places toward the top of the hill benches were observed which usually predicate a firm ledge either of limestone or sandstone, but nothing could be seen in either bench where the creek passes over them except loose limestone fragments. The limestone of the hilltop, however, proved to be the same as that found at the quarry opened by the military prisoners in the high ridge on the western part of the Reservation at Fort Leavenworth. It is the equivalent of Broadhead's No. 150 in

Missouri, and, without question, of the Oread limestone of the Kansas river section (see chapter VI). On the Reservation its surface is far above that of the country in Missouri across the river. In Missouri it is not found until a point much higher up the river is reached. On the north end of the high ridge of the Reservation there seems to be a cropping of limestone about 12 feet below this heavy rock, which may be the equivalent of the lower Oread limestone, and also the thin, even bed, which is but five feet below the heavy rock at Atchison. Professor Knerr gives the limestone in his Atchison section (chapter VIII), which I failed to see, and which he makes to lie yet below the even bed some few feet, unless the little exposure seen immediately above the coal mine, two miles down from Atchison, were it. In taking measurements on the side of a bluff often there is danger of error on account of portions of the limestone having moved downward more or less by the wearing away of the underlying shales. Therefore the separation at the Reservation might not have been as much as 12 feet. The Oread limestones at Lawrence, and west of there, are 20 feet apart. On the Missouri side of the river, before No. 150 of Broadhead is reached, in the upward survey, two limestone systems come in below this heavy limestone which are separated by about 20 and 50 feet of shales, etc., respectively. The benches two miles above Kickapoo may be formed by these thin systems, which in Missouri nowhere reach a thickness greater than seven feet.

The fossils of this limestone here are: *Spirifer cameratus, Athyris subtilita, Allorisma subcuniata, Allorisma granosa,* and others.

At Oak Mill station, a mile and a half above the last mentioned section, the Oread limestone has been quarried somewhat in the tops of the hills. It is here a light gray in color and 15 feet of it was exposed by the quarrymen. It is, however, thicker here than this. The fossils in it were: *Chonetes granulifera*—a shell found more abundantly as we ascend geologically—*Spirifera kentuckiensis, Zeacrinus mucrospinus, Zeacrinus acanthophorus, Archaeocidaris* spines, *Orthis carbonaria, Cyathaxonia distorta,* etc.

Going on to a point one and a half miles above Oak Mills the sand rock of the section three miles down the river is here seen at the water's edge, and the shales immediately above it for 20 or more

feet contain many fine fossils. These shales are the equivalent of Broadhead's No. 125 of western Missouri, where they are also filled with the same fossils. The fossils are: *Myalina subquadrata, Myalina recurvirostris, Bellerophon bicarinatus, Nucula ventricosa, Astartella* ———, *Lophophyllum proliferum, Athyris subtilita, Bellerophon carbonaria, Schizodus* ——, *Productus americanus, Productus nabrascensis, Edmondia* ———, *Crinoid* columns, *Pleurotomaria broadheadi,* and three other *Pleurotomarias, Euomphalus rugosus, Derbya crassa, Polyphemopsis nitidula, Leda (Nucula) bellistriata, Chonetes granulifera, Turritella* ———, *Zeacrinus mucrospinus, Zeacrinus acanthophorus, Orthis carbonaria, Spirifer plano-convexus,* etc.

It is worthy of note here that few of our shales carry fossils, except where there are thin layers of carbonaceous matter in them; yet here we have a seemingly mixed arenaceous and carbonaceous clay shale charged with perfect specimens of Molluscan exuvia, among which Lamellibranchs and Gasteropods predominate. There is a blue clay shale in Kansas City, Mo., lying below the Iola limestone, which contains many fine Crinoidia and Molluscan remains; but the same shale in other places fails almost entirely to yield any fossils. A few other of the bituminous shales of Kansas City yield three or four species of fossils. This fact is noted in describing the Kansas City and neighboring rocks.

From the last mentioned point, for about six miles up, and along the Missouri river, the bluffs are low close to the side of the stream and consequently nothing was seen of our heavy top rock, or any other stratum, until the coal mine two miles below Atchison was reached. There is an 11-inch vein of coal worked here by drifting into the side of the bluff which overhangs the river valley. The coal seam is 14 feet above the railroad track, and 16 feet above this coal about 2½ feet of limestone appears. Some distance above this limestone the perpendicular escarpment seen through the underbrush would indicate that our heavy limestone was there, were it not to be seen a little farther on up the river. One mile down from Atchison union depot and at intermediate points, quarries are worked, which give good opportunities to see the thickness, nature, etc., of the rocks passed. The quarry farthest down the river shows 21 feet of the heavy gray or Oread limestone (No. 150, Broadhead) and the same

system as that found in the high ridge of the Fort Leavenworth Reservation. Above it here are six feet of blue and drab shales, then 5 feet 8 inches of even-bedded limestone of splintery fracture. About 5 feet below the Oread limestone here there is a bed of blue and bituminous shales, then an even-bedded layer of limestone from 2 to 2½ feet thick. Here the base of the Oread limestone is 48 feet above the railroad grade, and at places arenaceous shales are exposed in this slope. The fossils of the Oread limestone are few here and of the common species. A quarter of a mile nearer the city is the Waggener quarry, where the Oread limestone is 22 feet thick. The first rock above, one-fourth of a mile away, which we have said was 5 feet 8 inches thick, is here but 8 inches thick at the south end of the quarry and thins out to nothing before the north end of the exposure is reached. Above this there are 20 feet of blue and drab shales, and then 3 feet of even-bedded limestone. Then above this 48 feet of slope, until a limestone 6 to 8 feet thick is reached. This we will provisionally call the Sea Urchin limestone on account of the quantities of *Archaeocidaris* spines which lie immediately above it in the clays. This would indicate that probably it is in the geologic horizon of the Topeka limestone. Above this again is a slope of 12 feet; then a thin limestone from 1 to 2 feet. Above this Professor Knerr, of Midland College, Atchison, says that in the high hills of the neighborhood of Atchison two other systems or parts of one system are found. First above the last-mentioned rock are 2 feet of soft, bituminous shales, then 2 feet of limestone, then 2 feet of clay shales, and lastly 2 or more feet of limestone.

At the union depot in Atchison the Oread limestone is 21 feet thick, and its base 35 feet 9 inches above the railroad. Below it are first five feet six inches bituminous and blue shales, then the even-bedded limestone two feet three inches thick, and lastly the blue and drab shales to railroad grade. The Oread limestone here is somewhat oolitite near the top, but this may be the result of coalescence with the limestones above it. It also contains some chert in places, but this a characteristic of this great limestone bed wherever found.

SECTION AT ATCHISON. (Fig. 3, page 66.)

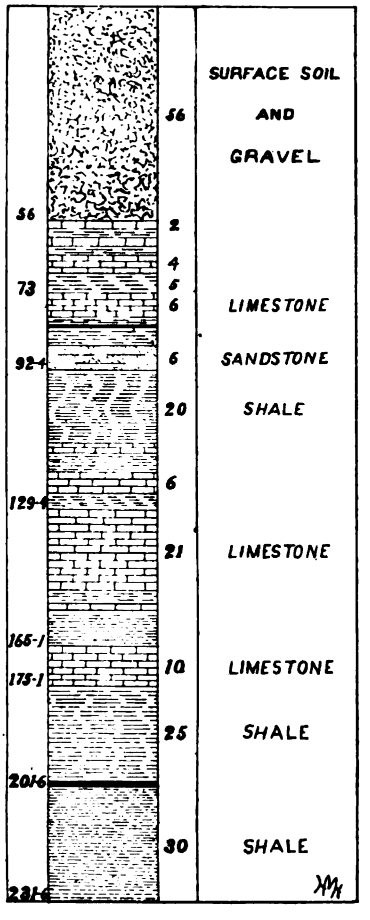
The fossils of the Oread limestone in and around Atchison are *Fusulina cylindrica, Productus costatus, Retzia mormoni, Spirifer cameratus, Fenestella* ———, *Spirifer plano-convexus, Allorisma subcuneata,* and *Crinoida.* The even-bedded limestone just below it abounds in *Chonetes granulifera* and also contains *Productus nabrascencis, Productus costatus, Derbya crassa, Myalina subquadrata,* etc.

From Atchison to St. Joseph, Mo., the general trend of the Missouri river is northeast and southwest. Going up the river, therefore, from Atchison the strata crops out on an almost horizontal plane, on account of the generally uniform northwest dip. From Atchison, therefore, to Doniphan station, which is almost due north, the rocks dip but little and the Oread limestone at the latter place is just above the railroad track. Along the bluffs, therefore, until Deer creek is reached, where this marked limestone is cut off by the valley of that and Independence creeks at their confluence in the northeastern part of Atchison county, it is almost in a horizontal position, as seen everywhere along the bluffs.

After reaching Independence creek our section instead of going northeast along the river leaves the Missouri here and runs up the valley of Rock creek in a northerly direction, towards Troy Junction in Doniphan county. Leaving Doniphan station, on the Burlington & Missouri River railroad, the grade rapidly rises until Troy Junction is reached, but the rock stratum seems to rise with it. A mile above Doniphan station the Oread limestone is still to be seen in the bed of the creek, and not much below the level of the track. The base of it only is in sight, resting as usual on its slaty, bituminous, and clay shales, below which again is seen the even-bedded limestone. These bituminous shales here contain many small concretions, and a little below the even-bedded stratum, or first limestone below the Oread, are found in great abundance, *Derbya crassa.* Here also *Chonetes granulifera, Myalina recurvirostris,* and *Myalina subquadrata,* are found quite plenty.

Figure 3.

SECTION at ATCHISON



SECTION NEAR DONIPHAN.

Two miles farther on up the grade, and three miles from Doniphan station, was found the first exposure where measurements could be taken; yet the benches formed by the Oread limestone could be seen for nearly two miles up the valley, above where last section was taken. Here a bluff was capped by a 15-foot system of limestone, immediately below which is 11 feet of buff and drab shales, then three feet of decaying limestone, then 50 feet of arenaceous shales, and 26 feet more of slope, bringing it down to the railroad grade. This upper limestone may be the equivalent of that which Professor Knerr reports as existing in the hilltops around Atchison. Three miles farther up the creek it comes about to the level of the rapidly ascending railroad grade, and is last seen in a west branch of Rock creek a mile or so above Brenner station.

OVER THE DIVIDE.

After leaving the point where the limestone last mentioned disappears the railroad grade raises rapidly to the summit of the divide at Troy Junction. This divide extends from southwest to northeast across Doniphan county and rests no doubt on a great anticlinal which gave contour in the early ages to the country and the course of the Missouri river. The river in first cutting its way from the northwest struck this and bent away to the east end of it before crossing it. After crossing it, the course of the river was to the south by what is now St. Joseph, Mo.; then it deflected back to the southwest towards the site of the city of Atchison. This gives Doniphan county a very extensive frontage on the river, being its boundary on the north, the east and part of the south. This divide was much added to by glacial drift, the deposit being of great depth on it, and above this till and gravel were deposited joint clays, of the Champlain Period, increasing its altitude. On the south side of this divide wells have been dug to a depth of 100 feet and more, and then ending where water was found among the loose sand and gravels. There was no stratified rock; boulders of granite and limestone alone being found, proving conclusively the drift origin of the upper deposits of this high divide.

After leaving Troy Junction the railroad heads in a northwesterly

direction down one of the tributaries of Wolf river. The down grade is so great here that two miles before Fanning is reached the stratified rocks again come into view, yet not much exposed until that station is reached. Seventy-three feet above the railroad tracks the base of Broadhead's No. 186 is found here, and some little distance down the hillside loose limestone was found indicating that there was another system at this horizon.

North of Fanning a milé and three-quarters and one-half mile from Highland station, section 28, township 2 south, range 20, in a farmyard there is a good exposure of the heavy limestone of last section. It is here 13 feet thick. Below it is 4 feet of buff shales, then an even bed of limestone 2 feet thick; and below this 6 feet of drab shales, below which again is 1½ feet of limestone, then a slope across a pasture lot of 20 feet to the railroad grade.

A mile and a half above Highland station and about directly west of Eagle Springs, is a quarry in the limestone close to the railroad tracks and but 9½ feet above them, having also its first thin stratum in place below. Here it presents the usual characteristics as at Highland station, and a few fossils were taken from it here. There is a thick, uneven layer at the bottom, where are found a greater number of fossils. At this point it is a blue drab and in part crumbling limestone. The organic remains are *Rhynconella uta, Lophophyllum proliferum, Fusulina cylindrica, Athyris subtila, Chaetetes* ———, etc.

Northwest from this, near the railroad, in a barnyard, in section 7, township 2, range 20, this same heavy ledge is again exposed, and the bottom of the thin limestone here is about on a level with the railroad grade.

Farther on one mile, on section 6, at the point where the Missouri river was again reached, the same limestone lies just above the track. A a little farther on, three-quarters of a mile from Iowa Point depot, on the Burlington & Missouri River railroad, a good exposure of this rock was found at the water's edge, and it was here 15 feet thick. The current of the Missouri river sets in here against it, and it forms a barrier to the usual rapid inroad of that stream. A good section was here taken of what was exposed of the lower thin sys-

tem of limestones in the bluffs and overlying this heavy limestone system.

The 13-foot system here (No. 186, Broadhead; see Rep. Mo. 1872, pt. 2, p. 133,) contains fossils already noticed in it at Eagle Springs station. Above it was a slope of 28 feet, then 5 feet of limestone somewhat argillaceous and parted in the middle by a heavy clay seam, then 11 feet of clay shales, except near the top, where they were bituminous, then 1 foot 6 inches of limestones with calciferous shales above it for some distance before a heavy joint clay deposit was reached, which joint clay extended to the top of the bluff.

The calciferous shales and top limestone contain *Chonetes granulifera, Bryazoans, Fistulipora nodulifera, Rhombopora lepidodendroides, Productus nebrascensis, Spirifer cameratus, Terebratula bovidens, Athyris subtilita, Archeodaris* spines, and *Crinoid* columns.

The 5-foot limestone contains: *Zeacrinus macrospinus, Zeacrinus acanthophorus, Athyris subtilita, Retzia mormoni, Spirifer cameratus, Productus costatus, Productus prattenianus,* and *Chonetes granulifera.*

On the face of the hill and in the heavy rock were found, in addition, *Productus semireticulatus, Orthis robusta, Cyathaxonia distorta, Chaetetes* ———, *Lophophyllum infundibulum* (?), *Fusulina cylindrica, Rhynchonella uta,* and *Naticopsis wheeleri.*

A few rods east of the depot at Iowa Point there is a good exposure of the thin systems which lie above the heavy limestone. This rock, which was exposed along the levee when the place was first settled, is now under a cultivated field on the river bottom land. The river bank is now nearly a mile away from the old landing of the early days.

SECTION AT IOWA POINT.

From Iowa Point to White Cloud, and in fact to the Nebraska line, very little is seen except the vast hills of joint clay, and these the most extensive of any found along the Missouri river in Kansas. At White Cloud are two thin seams of limestone, one just above the valley and close to the railroad track, 2 feet thick, in two layers, and an even-bedded layer, close to the water's edge, 16 inches thick, which were the equivalents of upper layers at Iowa Point. Above White Cloud, for a mile or more along the bluffs, there were

above these limestones somewhat heavy beds of drab clays, in which were thin seams of sandstone. The glacial drift lies on these shales, and above all are immense bluffs of joint clays rising from 200 to 300 feet.

As can be seen, the line of our section left the Missouri river at Doniphan station, striking it again just below Iowa Point. A few observations, however, were made on the east side of the county, and also north of Troy, the county seat.

First, going down Mosquito creek directly north of Troy, to the Missouri river. About a mile from the town the first limestone is seen. On the top of the exposure two thin layers were visible, separated by about 2 feet of shales, then a little lower a 10-foot ledge of limestone (No. 186 of Broadhead), then a couple of miles or so farther down two other thin systems of limestone, 2 and 4 feet thick respectively. The 4-foot ledge was but 10 feet above the water in the Missouri river, and 10 feet above that the 2-foot ledge, with shales above the latter.

Going on the downward grade of the Grand Island railroad, from Troy to St. Joseph, Mo., there are several exposures. One-half mile from Troy east is the heavy top rock of Brenner (No. 186, Broadhead). Five feet or so of it only could be seen. At Blair station the thin limestones below it are visible. West of Wathena one mile the heavy gray Oread limestone of Atchison appears in the railroad cut. At Wathena, a village on the river bluffs, the Oread rock is 110½ feet above the railroad grade at the depot. In the quarry here but 15 feet of it were exposed. It has all the lithologic and paleontologic characteristics here; small quantities of chert, and not many fossils, although various forms were found, and some few fossils in good preservation. This limestone is also present everywhere along the Missouri river in the bluffs from Atchison to Wathena and up to the point opposite Amazonia in Missouri. At Amazonia the river bends rapidly to the west, and this limestone is soon lost sight of in the general northwesterly dip. To determine the exact extent of its outcrop in Doniphan county, a more detailed survey must be had. At Amazonia, in Andrew county in Missouri, this limestone is well exposed. A mile and a half west of Amazonia station, on the Kansas City, St. Joseph & Council Bluffs railroad,

there is immediately above this heavy limestone and separated by about 2 feet of shale, a somewhat oolitic stratum, 14½ feet thick, which is the equivalent of the rock that pinches out entirely at the Waggener quarry at Atchison, and which lies there 4 feet above the heavy limestone deposit. But this is the peculiarity of some of the limestones, especially those of arenaceous and oolitic structure. They disappear and come in again in their proper place. For instance, the rock at the top of the smelter quarry at Argentine and the very top rock at Kansas City, Mo. (No. 1 of Kansas river section), appears but at few places. At Edwardsville, in Wyandotte county, it is in its proper place, but at Pomeroy, in the same county, it is not seen, nor at Quindaró, while at Connor there is a small outcrop of it, and also another at Ross, in Leavenworth county.

All the thinner systems also are subject to this want of persistency, although not in so marked a degree; but the heavy systems, and especially the gray limestone, are of a very great lateral extent and nearly of uniform thickness.

A few general remarks may be made here on the section from Kansas City to the Nebraska line. After leaving the Kansas City systems of limestones, the two heavy deposits, as seen in figure 3, outcropping at the Soldiers' Home and south of there are undoubtedly the equivalent of the Garnett systems, only that the lower of the two is not as thin as the same at Eudora, and agrees with it more as it appears at Olathe in point of thickness, and the characteristic fossil, *Syntrialasma hemiplicata* was not seen in it. The lower, however, we are now persuaded, is the same as the Plattsburg system of Broadhead—his No. 108—and the upper, his No. 112.

The ferruginous brecciated limestone of the lower quarries of Fort Leavenworth may be the continuation of the thin limestone system in the Lawrence shales, seen at the horizon of that town. The upper Oread and the heavy limestone of Atchison must also be considered as equivalents.

CHAPTER III.

A GEOLOGIC SECTION ALONG THE NEOSHO AND COTTONWOOD RIVERS.

BY M. Z. KIRK.

A.—THE NEOSHO RIVER SECTION.

THE CHEROKEE SHALES.

The northwestern limit of the Mississippian or Sub-Carboniferous formation along the Neosho river was not definitely determined. It may be at a point about 14 miles below the south Kansas line, at the top of a sandy limestone system which now and then assumes a shaly aspect; or it may be some miles below Miamitown, a little further down the river. Nothing exactly corresponding to this formation is known within the state along the contact line between the lead and zinc bearing limestone of the Mississippian and the Coal Measures, although frequently a sandstone seems to lie at the

base of the latter. Above this point for 15 miles or more nothing is exposed along the river bluffs but shale, which here and there assumes such an arenaceous character that it would almost do to be called a sandstone, and a few seams of coal which usually are so thin they have but little commercial value. The Cherokee shales along the Neosho river have a slight dip to the northwest, but about a mile and a half below the mouth of Four-Mile creek there has been a considerable disturbance. The shale here has a dip to the southeast of four feet to the hundred yards. Coal is mined for local use from numerous small veins in the vicinity of Melrose. There are also several small "strippings" between Chetopa and Oswego.

The first limestone system encountered is a thin bed found about seven miles below Oswego, but on the hilltops it reaches farther south. This limestone is not very prominent in the adjoining country, and in many places it is either concealed by the soil or entirely fails to exist. Possibly it should be correlated with the thin limestone occurring near Cherokee which is shown in plate II. A number of other thin limestones have been noted in the Cherokee shales, but presumably they are of little stratigraphic importance, so they will not be considered here.

THE OSWEGO LIMESTONE.

As Oswego is reached the Oswego limestones are found capping the hilltops to the west of the Neosho river. They are fully 450 feet vertically above the Mississippian limestone, as shown by the Oswego well in plate III. The Oswego limestone consists of two systems, which are separated by a bed of about 4 or 5 feet of shale. In the environs of Oswego each limestone is about 10 feet thick, but they thicken considerably to the westward, so that six miles out the upper one is 21 feet and the lower one 24 feet, as shown by the record of a well near Stover. To the northeast the Oswego limestone reaches to Fort Scott and even farther. It caps the high hills on the divide between Fort Scott and Pittsburgh, reaching an altitude of fully 1,000 feet above sea level, from which point it dips to the southwest to Oswego at about four feet to the mile. By reference to plate III, one sees that the Oswego limestone is about 740 feet above sea level at Osage Mission. The altitude at Oswego being

899 feet, and the distance about 25 miles, gives the rock a dip to the north of about 10 feet to the mile. The greatest dip is probably to the north of west.

The character of the two strata of the Oswego limestone is very similar. Each stratum is composed of a number of distinct layers; each one also is relatively rich in fossils. Brachiopods occur in considerable abundance and well-preserved fossil coral is plentiful, particularly in the upper one, as is given in detail by Mr. Bennett in chapter IV. The rock is a compact, solid limestone of a light buff color and is suitable for building purposes of all kinds when it can be obtained of sufficient dimensions. In addition to the fossils the upper one contains quite an abundance of flint nodules.

The first shales below the lower limestone and the one between the two are intensely black, and are filled with nodular concretionary bodies from a half inch to three-fourths of an inch in diameter, and which help to recognize the shales. At Oswego the limestone is fully 120 feet above the water in the river. It can be traced over the bluffs and along the hills to the vicinity of Laneville, where it disappears under the river. Throughout this entire distance these black shales are very prominent.

The Pawnee limestone is separated from the Oswego by 30 or 40 feet of sandstone and shale. It occurs on the first hilltops north of Laneville, and caps the hills to the southwest. It disappears under the water 8 or 10 miles below Osage Mission. This limestone is quite irregular, varying from 8 to 10 feet near Laneville to 25 or 30 feet near Redfield to the west of Fort Scott.

THE PLEASANTON SHALES.

Immediately overlying the Pawnee limestone are the Pleasanton shales which are over 250 feet thick as shown by the Chanute well in plate III, and also in plate IX, figure 1. About the middle of this bed vertically is found a small layer of limestone which is so thin and from the best records of so uncertain an extent that it will be mentioned only in connection with these shales. The Pleasanton shales in many places grade into many different varieties of sandstone that are of great importance on account of their thinness of layer and smoothness of surface, which renders them unusually

desirable for flagging stone. In section 13, township 30 north, range 20 east, on the land of A. G. Robinett, extensive quarries are opened, from which large amounts of flagging stone are taken to neighboring towns—Parsons, Osage Mission, and other places. At this point the Neosho river brushes against a precipitous bluff on the western bank, where a splendid section may be observed, as follows:

Surface soil and gravel, 5 feet.
Limestone, 8 feet.
Yellow to red sandstone, 8 feet.
Bluish sandstone, 45 feet.

It is the latter that furnishes the best flagging stone. To the northeast the same formation includes the famous Bandera and Gilfillan flagging stone which are shipped so extensively over the state and known as the Fort Scott flag. At each place the flagstones are quite shaly, so they lack a great deal of being pure sandstone. At other places they become more pure, the layers becoming thicker and would furnish good dimension stone. Mr. Josiah Kimmel has opened a quarry in such stone in section 23, township 30 north, range 20 east. Although sandstone seems to be so abundant, yet it should be clearly stated that the predominant part of the system is shale, so that it is properly called a shale formation. Within two miles to the south of Robinett's quarry this excellent flagstone is almost entirely changed to a shale. These flags and red sandstones are covered by the thin irregular layer of limestone, as shown in the section given above. This rock formerly was quarried quite extensively along the river to the south of Osage Mission. To the west of Osage Mission the Pleasanton shales are quite varied in character, portions of them being dark and bituminous while other portions are light colored and arenaceous.

THE OSAGE MISSION WELL.

The town of Osage Mission rests on the Pleasanton shales. Several years ago a well was bored here with a diamond drill to the depth of 700 feet, which passed through the limestone near the surface, the Pawnee limestone, the Oswego limestone and penetrated the Cherokee shales about 400 feet without passing through them, as shown in plate III and in plate XV, figure 2.

THE ERIE LIMESTONE.

Immediately overlying the Pleasanton shales one finds an important limestone which has been called the Erie limestone on account of its extensive development both north and south of Erie. It is exposed on the hilltops to the west and southwest of Osage Mission, but here it is only a few feet thick. It increases in thickness to the northwest until it reaches its maximum of nearly 100 feet between Shaw and Austin. This group is divided into three more or less distinct systems. Northeast of Erie, at Uniontown, these systems are entirely distinct, and Mr. Bennett has called it the Triple limestone. The great difference in thickness at different points is largely due to the planing off of the upper surface by erosion, producing a wedge-shaped mass. To the southwest the Erie limestone covers the high ground between the Neosho and Verdigris river and extends into the Indian Territory beyond Coffeyville. In this region the three systems are separated by heavy shale beds as shown by Mr. Adams' section in chapter I.

On the whole, the Erie limestone constitutes one of the most extensive and most important limestone systems in the state. This is by far the heaviest and most constant limestone system reached thus far above the Mississippian. The quality of the Erie limestone is varied. Where it is weathered it seems quite porous, due to the unequal degree of solubility of the rock. In protected places it is firm and compact and would make an excellent building stone. At one place in a railroad cut between Shaw and Erie the rock assumes a wonderfully brecciated texture. The extent of such a texture was not determined, but it must be quite limited, for nowhere else was it observed.

THE THAYER SHALES.

Above the Erie limestone is another system of shales and sandstones which to the northwest reaches a thickness of about 100 feet, as given by Mr. Bennett in chapter IV. Along the Neosho river section it possibly does not exceed 90 feet, and the drill records at Iola show the shales to be even less than 75 feet. It reaches its maximum thickness to the southwest and for this reason they were named the Thayer shales in chapter I. This system is first encoun-

tered on the high hills northwest of Osage Mission. These shales and sandstone to the south of Chanute and west of Austin have not been protected by a strong limestone system and hence the hills have been weathered and rounded. At places along the eastern bank the sandstone has increased in thickness and the weathering has been more irregular. Here as elsewhere sandstone appears and disappears with great readiness. Around Thayer the sandstones appear in heavy beds, some of which produce excellent building material.

THE CHANUTE WELL.

The Chanute well record gives us a very good check upon our stratigraphical work, as shown in plate III and plate XIII, figure 2, The latter gives the exact thickness of the different strata passed through. By reference to plate III it will be seen that this well was begun in the Thayer shales and passed through the Erie limestone, the Pleasanton shales, the Pawnee limestone, Oswego limestone, Cherokee shales, and into the Mississippian limestone. This give us a vertical section at this place of 960 feet, and permits us to determine the dip of all the strata from Oswego towards the northwest. The surface of the Mississippian at Oswego is 390 feet above the sea level and at Chanute is 40 feet below sea level. The distance is 42 miles, which gives us a dip of a little more than 10 feet to the mile. At Chanute the Cherokee shales have about the same thickness as at Oswego, so the dip of the Oswego limestone is the same as that of the Mississippian.

THE IOLA LIMESTONE.

To the west of Chanute the hills are covered with a thin stratum of limestone. As we trace it to the north we find it gradually grows thicker until we reach Iola where it is 40 feet thick. Along the section from Chanute to Iola we have a splendid illustration of the way erosion has worn this great mass of limestone down to a feather edge, as seen at Chanute and along the hills to the northeast and southwest. The Iola marble quarries are situated in this system, and for this reason it has been named the Iola limestone. It is probably the heaviest and most persistent limestone in the

state. It has been traced from the south side of the state west of the Verdigris river to the east line of the state near La Cygne, and from there northward to Kansas City, where it constitutes the heavy limestone near the tops of the bluffs, as shown in plate II and plate VI of this report. The character of the rock is remarkable, particularly regarding the unusually thick layers it produces. In this respect it surpasses any limestone system in the state. On this account rock of almost any dimension can be obtained from it, as is practically demonstrated at the Iola quarries. The inclosed fossils, which are fully described by Mr. Bennett in chapter IV, often produce very pretty figures in a polished surface.

THE IOLA WELL.

We are so fortunate as to have the record of a diamond-drill well at this place, as given in plate XV, figure 1, and plate III, which not only gives the exact thickness of the Iola limestone, but all of the systems down to the Cherokee shales. The Iola well is found to agree almost exactly with the Chanute well, as it also does with the Humboldt well. These drill records are as accurate as could be procured, and the well sections are all drawn to scale and represent the exact facts. Having the records of so many wells it has been quite easy to correlate the different limestone systems occurring in different parts of the state as shown by the dotted lines in plate III.

THE CARLYLE LIMESTONE.

Above the Iola limestone lies a bed of hard, sandy, brittle shale which has a thickness of about 75 or 100 feet, although in Iola it is probably not quite so heavy. Above this another limestone system begins, and is first seen below Iola forming a stratum of 4 or 5 feet, capping the bluff just northeast of the quarry in the Iola limestone. This upper system extends to the northeast and is abundantly exposed at the little railroad station, Carlyle, five miles north of Iola, and for this reason is known as the Carlyle limestone. Farther up the river from Iola it increases to the thickness of 15 or 20 feet, but is nowhere a very heavy limestone system. It is exposed along the hills to the vicinity of Neosho Falls.

THE LANE SHALES.

First above the Carlyle limestone is a heavy bed of shales which in some places carries large quantities of sandstone. The sandstone hills west of Neosho Falls are in these shales, which have been named the Lane shales (chapter II) on account of their prominence in the vicinity of Lane. Northeast of Neosho Falls is a broad, rich river bottom, while at Moody station the high sandstone bluff approaches the river. Just south of Moody these Lane shales are about 120 feet thick, and at this point they contain so much sandstone that the north and east sides are very precipitous.

THE GARNETT LIMESTONE.

To the west of Moody the high hills are capped with two strata of limestone which are separated by 8 or 10 feet of shale. This system was traced from these hills to the river at Burlington. To the south of Burlington are a number of quarries one of which lying east of the Taylor horse-farm has been worked quite extensively. These strata are quite thin, being only 10 or 12 inches respectively two miles south of Burlington at the above-named quarry. On account of its prominence around Burlington this system has been called the Burlington limestone, but it is also quite an important system near Garnett, so it may bear the name of Burlington or Garnett limestone. This system has a peculiar blue color, which is especially noticeable near Burlington. The upper stratum is a good building stone while the lower crumbles upon exposure.

THE LAWRENCE SHALES.

Above the Garnett limestone is a heavy shale formation which in places is quite sandy. It has been traced to the northeast to the vicinity of Lawrence where it constitutes a heavy and important shale bed. It has been known as the Lawrence shales. It extends several miles above Burlington, producing the wide bottom lands in that vicinity. The small hills to the west are very much eroded and rounded until we reach the Strawn limestone which commercially is rather an unimportant system. It is exposed along the hills to a point a short distance above Strawn station.

THE HARTFORD LIMESTONE.

The limestone which passes under the river at Hartford will be called the Hartford limestone. It is separated from the Strawn limestone by at least 60 feet of sandy shale which is exposed along the bluff near the railroad above Strawn. The Hartford limestone at this place has a peculiar appearance and weathered surface caused by the small seams in the stone being filled with crystals of calcite which have resisted weathering better than the surrounding limestone material. At the bridge about a mile east of Hartford this limestone is of a light color where it is exposed to the weather.

The next limestone system above the Hartford is separated from the latter by about 50 feet of shale. At the church just south of the junction of the Cottonwood and Neosho rivers another limestone system is seen on the top of the hills from which place it extends up the river almost to Emporia. It will be known as the Wyckoff limestone, as it is prominent in the vicinity of that town. It is exposed at Humphrey's ford and is about 4 feet thick in Coal creek to the southeast.

THE EMPORIA LIMESTONE.

Above the Wyckoff limestone is a heavy bed of shale as exposed along the hills to the southeast of Emporia. In the road and ravines to the north of Wyckoff occurs the Emporia limestone. It was first seen in Chicago Mound, which is near Wyckoff, and is by far the largest hill in this vicinity. This rock has been quarried to some extent at Emporia and to the northeast it has been quarried for street and bridge purposes. This system disappears under the river, near Emporia water-works.

THE AMERICUS LIMESTONE.

Above the Emporia limestone is quite an extensive shale bed as seen on the water reservoir hill at Emporia. The hills to the north and west are capped with two thin layers of limestone which are about 4 feet apart. This system is of greatest commercial interest west of the river opposite Americus, in the northwest quarter of section 9. At this place it is about 20 feet above the river bed. The upper stratum is of a bluish color while the lower is a light

buff stone and is about 16 inches thick, very solid and compact. Splendid dimension stone has been taken out of the Stevens quarry at this place to be used at Emporia, Hartford and elsewhere. The position of the Americus limestone is shown in plate III.

THE COTTONWOOD FALLS LIMESTONE.

Passing on up the hill to the west from Stevens' quarry one crosses a shale bed about 50 feet in thickness before reaching the lower Dunlap limestone. This system is composed of two strata separated by about 20 feet of blue shale. The upper stratum furnishes some good stone at Dunlap. The system is of much less importance than the one about 25 or 30 feet above it which is known as the Cottonwood Falls limestone. The latter is exposed upon the hills north of Dunlap and can be traced along the hillside to the Joseph Dutcher quarry about three miles northwest of Dunlap. Here the limestone is 5 feet 6 inches thick and is quarried quite extensively for railroad and building purposes. It is a very pretty light colored stone and can be obtained in large blocks. It is also quite easily cut into pieces of any desired size and shape. Material is shipped from this quarry to various parts of the state. Although the stone is first-class they are not as well supplied with machinery for cutting it as at Cottonwood Falls and elsewhere. This Cottonwood Falls rock passes under the surface near Council Grove.

SUMMARY.

This completes the Neosho river section from the Mississippian formation to the Cottonwood Falls limestone. In making the drawings for the sections given in plate III it was found necessary to exaggerate the thickness of nearly all the limestone systems and at the same time some small shale beds had to be omitted. In the drawing only general facts could be represented but this has been done with as great accuracy as possible. The section given in plate III represents all the important limestone systems, but future study may and probably will develop a few more small systems.

B.—THE COTTONWOOD RIVER SECTION.

From Wyckoff to Cedar Grove.

Let us now return to the junction of the Cottonwood and Neosho rivers near Wyckoff and trace the section along the Cottonwood river, as shown in the lower part of plate III. The Wyckoff limestone, as has been stated, is seen along the Cottonwood river below Emporia at Humphrey's ford and elsewhere. This stone is separated from the Emporia limestone by 40 or 50 feet of shale. As we pass up the Cottonwood river the Emporia limestone is first observed along the hilltops about four miles south and one mile east of Emporia. It is also exposed on the top of the hill just south of the church in section 33, township 19 north, 11 east, at which place the limestone is about 5 feet thick. It continues westward, but as the surface rises rapidly it soon passes under the ground. This system is characterized by being so full of seams that no large pieces can be obtained. Mr. Curtis has a quarry in section 28 of the township mentioned above. He finds a considerable market for the rock in Emporia where it is used for walling cellars, wells, and for making other structures for which large dimension stone are not required.

PHENIS MOUND.

As one approaches Phenis Mound (which is probably twice as high above the river as any hill near it and is approximately 300 feet above the river) from the Curtis quarry one crosses at least 40 feet of shale before striking another limestone system. This limestone appears in a small ravine about half way up the mound and extends to the northwest beyond Plymouth. Thirty feet above this another limestone system is found which is composed of two strata separated from each other by 10 or 12 feet of shale. It extends almost to Cottonwood Falls, and is seen along the branch railroad just east of the Cottonwood Falls quarry. It has been quarried at a number of places between Phenis Mound and Cottonwood Falls but not very extensively compared with the work done in the heavy limestone 30 feet above.

THE COTTONWOOD FALLS LIMESTONE.

This important limestone system appears on the summit of Phenis Mound, eight or nine miles below Cottonwood Falls. At this place a few small porous fragments are found covering an area about 25 feet square at the very summit of the mound. This system is quite prominent at the famous stone quarries owned by the Retticker Brothers, about 2½ miles east of Cottonwood Falls. At this place we have the following sections:

Beginning on the hilltop we find about 30 feet of soil, gravel and shale, in the latter of which marine invertebrate fossils are unusually abundant. They weather out on the hillside above the limestone. Below this is the Cottonwood Falls limestone, which is composed of two layers, the upper one being 2½ feet thick and the lower one 3. Each layer is remarkably uniform and particularly free from vertical fissures. These properties render the stone the most valuable for building purposes of any thus far extensively operated in the state. It is possible to obtain masses of almost unlimited size with a thickness of 2½ or 3 feet. By splitting or sawing the layer, flagging stone of any desired thickness and 20 or 30 feet long can easily be obtained. Below this stone is about 30 feet of shale, but it is not nearly so silicious here as along the Neosho river. Below this is the upper stratum of the Dunlap limestone system. In character the rock is quite similar to the Cottonwood Falls limestone and has been quarried considerably, but the operations were finally abandoned on account of the thinness of the layers and the large amount of stripping necessary. Below another 9 or 10 feet of shale the lower stratum of this system is found. It differs radically from the upper one, being much finer grained and more compact in texture, and in having so many vertical fissures that it is impossible to work it into dimension stone. Yet for ballast and for structural purposes where small pieces are wanted it is quite valuable. It has a subconchoidal fracture, a dark bluish gray color, and its blocks are so angular that it is locally known as "joint-rock."

ANTICLINALS AND SYNCLINALS IN THE COTTONWOOD FALLS SERIES.

Although the Cottonwood Falls limestone passes downward out of sight about a mile above Strong City it again appears about two miles farther west. There is thus produced a very pronounced synclinal trough the limbs of which make an angle with the horizontal of fully 100 feet to the mile. The synclinal axis trends north and south so that the same conditions are observed on both sides of the river, although the valley here is fully three miles wide. In fact the exposures on the south bank are better than those on the north, so the irregularity in position can be better studied. As one passes westward along the wagon road from Cottonwood Falls the limestone is seen to pass under the first little hill west of the town and is seen no more throughout a distance of about two miles. Suddenly it is seen to rise out of the ground making an angle of three degrees with the horizontal. The first limestone beneath it also appears only a few rods further west, so that seemingly the two are entirely conformable with each other. From this place they continue to rise westward to the high hilltop just east of Elmdale Mills. As this hill is higher than the one on which the Cottonwood Falls quarry is located and is five miles to the west one may readily see the importance of this great synclinal trough. Had the limestone continued to dip to the west at the angle common to most formations in this part of the state it would be at least 200 feet below the hill at Elmdale Mills instead of being on its very summit. On the north side of the river there are two synclinal troughs about a half mile apart. Along the side of one of these the dip for a short distance is fully four degrees, which is the equivalent of about 375 feet to the mile. Westward from Elmdale Mills the limestone is almost horizontal for several miles, but finally again dips to the west and passes out of sight between Clements and Cedar Grove. This is the most pronounced instance of either anticlinals or synclinals in the whole area of the Coal Measures. No evidence was available which had a bearing on the question of its cause, so that at present at least we are left in doubt regarding its origin. Its existence is a fortunate one, however, for this valuable limestone series is thereby again brought to the surface so that it may produce

a larger quantity of the most excellent building stone which it furnishes. The quarries at Elmdale Mills and Clements are located in it, and at many other points equally good opportunities exist for the opening of extensive quarries, which sooner or later probably will be done.

CHAPTER IV.

A GEOLOGIC SECTION ALONG THE MISSOURI PACIFIC RAILWAY FROM STATE LINE, BOURBON COUNTY, TO YATES CENTER.

BY JOHN BENNETT.

Section at State Line.
Section at Fort Scott.
The Oswego or Ft. Scott Limestone.
The Pawnee Limestone.
The Pleasanton Shales.
The Erie Limestone.
The Thayer Shales.
The Iola Limestone.
The Carlyle Limestone.

The line of this section, as can be seen on the accompanying state map, trends almost east and west. The road follows the valley of the Marmaton for nearly its entire distance through Bourbon county, then crossing over the divide reaches the valley of the Neosho river at Iola in Allen county, thence passing west again reaches the higher country at Yates Center in Woodson county.

SECTION AT STATE LINE.

Beginning in the bed of the Marmaton river, a mile or so east of the state line, in Missouri, we find near low-water mark, coal 15 inches thick; then above the coal 7 feet of shale, and again 4 inches of coal; then ascending through shale 4 feet there is another seam of coal 10 inches thick, then 4 feet more of drab and blue shales, and above this are 8 feet and 9 inches of very dark bituminous shales, the lower section of which for 2 feet is exceedingly firm and slaty in structure, having imbedded in it large concretions of very hard clays mixed with pyrite which will measure from 1 to 2 feet in diameter. These peculiar forms occur in connection with the Fort Scott coal, and will be noticed more at length when discussing them. Above

this firm stratum in the bituminous shale bed are two lenticular beds of argillaceous limestones which contain many specimens of *Productus cestriencis.* Capping all there is found what is locally known as the "diamond rock." It is a limestone in one stratum in which the vertical seams divide it into rhomboidal or diamond-shaped masses, from which the name is derived.

At the state line we find the same section in part. Our second seam of coal, however, is in the bed of the Marmaton, where, instead of 4 inches, it has thickened to 6 inches, and the 4 feet of clay shales above it and between it and the next coal has thickened to 10 feet. Into this shale there seems to have been interjected here and there bodies of a very hard rough rock. Figure 4 from Fort Scott shows the same formation. The upper seam of coal is here thickened from 10 to 22 inches. At this place the rest of the section was hidden by the soils of the valley until the "diamond rock" was reached, which stratum passes below the waters of the river a mile and a quarter to the west of the state line, and immediately below it in this latter place is found a thin seam of coal. A few of the common fossils of the Coal Measures are found in this rock.

SECTION AT FORT SCOTT.

Between the last mentioned limestone and the celebrated "rusty coal" of Fort Scott lies a heavy body of clay shales varying from 55 to 60 feet in thickness. At places between the state line and Fort Scott there are large exposures of it, and wherever so exposed it is concretionary in structure. In the bed of the river at Fort Scott there is a thin layer of limestone in the shale about 30 feet from the top. Here also, as seen in the railroad cut near the "plaza," is a peculiar structure. For some feet below its contact with the "rusty coal" small masses of limestone containing fossils are found in it. In places they look as though thrown in at random, then again they seem to pass down through it for several feet in vertical layers. See figure 4, illustrating this peculiar structure.

The "rusty coal," which lies above the shale varies from 13 to 20 inches in thickness, and is mined at the foot of the hills, generally by stripping, from the state line until it passes out of sight by dipping under the higher geologic strata three miles west of Fort Scott.

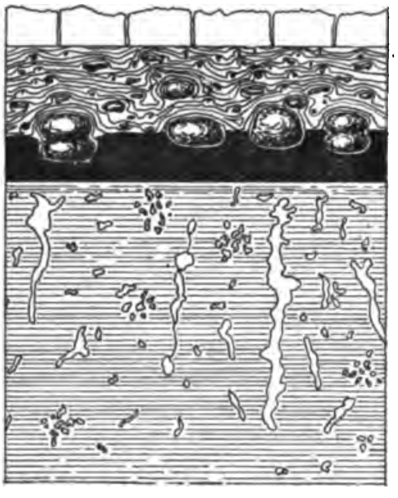
Over almost the entire eastern part of Bourbon county it has been mined continuously since the early settlement of the country, and it was the main source of fuel supply in early days to the Kansas City, Fort Scott & Memphis railroad. It is known in the markets as the "Fort Scott red coal."

Above this coal is a very dark bituminous shale 3 feet in thickness and in places very firm. Large spheroidal and sometimes compound spheroidal concretions a foot or more in diameter lie at its base, partly in the coal and partly in the slaty shale, (see figure 4). These concretions are generally somewhat flattened and are found at the doors of many residences in Fort Scott, where they are utilized as hitching posts, prepared simply by drilling a hole in one of their flattened surfaces, and fastening a ring therein. Many small ball like concretions, as well as irregularly shaped bodies, are to be found in this shale. They formed originally around some portion of a coal plant, the shell of a mollusk, a crustacean of the shrimp family, or tooth or dermal plate of a fish. They are of all dimensions, from half an inch or less to an inch in diameter, the irregular forms sometimes reaching six inches in length, but never thicker than the rounded forms. The predominating form which constituted the nuclei was the shell of the little brachiopod *Discina nitida.* While concretions similar to those which are found in this shale and the shale first above it are also found elsewhere, yet in no other strata of the region are they to be found in such lavish profusion. This shale is of great lateral extent and is noted for its persistent lithologic characteristics, being very dark and abounding in these nodular forms.

THE OSWEGO LIMESTONE.

Immediately above this interesting shale bed lies the first important limestone of our section. It consists of a single stratum which is 4½ feet thick, the vertical seams in which cut it into large blocks. These blocks are flat at their base, although they do not lie directly on the shales, for a few inches of argillaceous limestone comes between. This little seam grades from a pure buff clay to a firm rock structure, the firmer portions on some little exposure being easily split up into very thin horizontal sections. The upper por-

Figure 4. Kans. Univ. Geol. Surv.



Section at Fort Scott, showing calcareous concretions in the shale adjacent to the Fort Scott coal.

tions of the blocks are rounded, giving the surface where some time exposed a rough appearance. Where recently exposed this rough surface is leveled up by hard calciferous clays, the effect of which is to take away the rough appearance of the upper surface. The local name given to the limestone is the "cement rock," from the fact that the Fort Scott hydraulic cement is made from it. At the cement mill, north of the Marmaton, on the Kansas City, Springfield & Memphis railway, it is quarried extensively and burned by the underlying coal. On long exposure the limestone breaks into angular fragments of all dimensions, and it weathers buff, although originally of a light gray color. It is noted for its large crinoid remains—the calcareous columns of these plant-like animals reaching a diameter of 1¼ inches. They occur all the way through it, but more frequently in the clays immediately below. Exceedingly large varieties of *Meekella striato-costata*, *Productus punctatus*, *Athyris subtilita,* and other organic remains are to be found in it. A coral mentioned in the system of limestones above this has an existence here *(Chetetes milliporaceous)*, also another coral *Syringopora*.

Between the "cement" limestone and the system intimately associated with it above, is a stratum of clay and bituminous shales. The latter form the greater part, and at their middle lies a thin coal vein, nowhere over an inch thick along the Marmaton where seen, and frequently in the same region altogether wanting. At the summit of this shale is a yellow clay streak varying from 4 inches to a foot which yields a minute form of the characteristic coal fossil *Chonetes mesoloba,* also many of the dorsal valves of *Spirifer planoconvexus.* The concretions found so abundant in the bituminous shales below are found in like quantities and peculiar forms, in these similar shales above.

In our upward course we have now reached one of the most remarkable limestones in our whole series. It runs from 10 to 14 feet in thickness. The lower layers are somewhat evenly bedded, with frequent vertical seams, making it easily quarried. This part of it is fairly good building stone, as can be seen in many houses made of it in Fort Scott and the neighboring country. The upper section of it, however, is unevenly bedded, and tells the story of its origin so full of interest to the paleontologist. It takes him far back into

the dim and misty past, when innumerable polyp life built up their stony abodes, and left a coral reef for the citizens of Fort Scott to erect their homes upon. Vast quantities of this coral have been crystallized until scarcely a trace has been left of its original condition, but much of it is yet found with its cells as plainly visible as on the day the coral builder put his filmy parting in the honeycombed apartments which he builded so well. In geology his house is known by the name of *Chaetetes milliporaceous.** Everywhere skirting the hills of eastern Bourbon county this rock is to be found, and in Crawford county to the south are numerous and interesting exposures of it with its abundance of *Chaetetes milliporaceus.* This limestone extends east of Fort Scott into Missouri, and to the west is seen for the last time near the bed of the Marmaton three miles west and two miles south of the city. The Fort Scott, Springfield & Memphis railway rests upon it from Fort Scott to Fulton, a distance of 13 miles. At the latter place it dips below the surface, as is shown on plate II. Its general dip, like all the rocks of the country, is to the northwest, but locally its position is quite horizontal. Sometimes it even rises towards the west and again dips very rapidly, forming anticlinals and corresponding synclinals.

There are good exposures of this interesting rock at the military bridge, one mile east and one mile north of Fort Scott, and at the Missouri Pacific railway cut near the plaza in Fort Scott, where the whole series from 15 feet below the "rusty coal" up to this rock is exposed, as partly shown in figure 4; again on the west side of the city by the cutting for the Minden branch of the Missouri Pacific railway, and again on the Missouri, Kansas & Texas railway to the southwest of the city three miles.

In the lower section of this limestone the abounding and characteristic fossil is the *Spirifera martinia*, specimens of which can scarcely ever be taken out of their firm matrix in good condition. The coral so abundant in this system is nevertheless found in great quantities in the next limestone above, at its very summit, but it has not the lateral extent, as far as observed, which it has in this one. These two limestones combined, the "cement rock" and the coral-

*According to Zittle, this is not a coral, but a mollusk of the order Bryozoa.

bearing rock, have been named the Oswego, or Fort Scott limestone.

Over this limestone is a heavy bed of arenaceous and somewhat micaceous shales, varying from 35 to 60 feet in thickness. At the state line it is 60½ feet thick, at Fort Scott but 39, and at Rock school-house, four miles southwest of Fort Scott, it is 80 feet thick, made so probably by the rapid dip of the limestone immediately below. The dip to the west here is 25 feet in 1,500 feet.

Near the base of this shale bed and at its summit are everywhere to be seen two bituminous layers, the lower one yielding some coal in one place southwest of Fort Scott, where it is mined by stripping. Here it is an intensely black coal and lies in a bed of blue clay shale, not a particle of bituminous shale being in connection with it. This was a feature nowhere else seen in the coal deposits of Bourbon county.

Dividing this whole body of shale into nearly three equal parts there are again two other streaks of bituminous deposits, which, in a few places, yield small quantities of coal. One of these coals, the upper, is capped by a calciferous clay quite cemented in places, and largely made up of broken shells and crinoids. There are many fossils in it unbroken but so covered and cemented in the clays that clean specimens cannot well be secured from it. The prevailing types are *Derbyi* (hemipronites) *crassus, Chonetes mesoloba;* (in abundance) *Athyris subtilita; Tophophyllum proliferum; Campophyllum torquim, Zeacrinus*, and a small gasteropod.

Near the top of this shale at the Missouri state line, but 16 feet from the limstone above, is found 2 or 3 feet of gray limestone in thin layers from half an inch to 3 inches in thickness, which may be called, for want of a better term, shelly lime rock, on account of its laminated condition. This rock is not seen as far west as Fort Scott, but has an equivalent in a calcareous clay of a few inches, and containing fossils such in all respects as I have just above described. These shales carry sandstone in certain localities which are quite firm, but possibly not firm enough for building purposes. Such a condition is found a couple of miles west from the state line, in the road, directly east of Fort Scott.

THE PAWNEE LIMESTONE.

The next rock in superincumbent order to this is a limestone, of which much is exposed in Bourbon county. It is in its total thickness where seen 35 feet, but thickened according to the records of a well at Redfield to 52 feet. In many places where lying at the surface of the country it is a tough, ferruginous rock, somewhat brecciated in appearance. Great boulders of it cover the country in places and lie partially imbedded in the soils. The lower portions of it cap the hills from the state line to some little distance west of Fort Scott, where it comes down to the common level of the country and begins to show its full thickness before disappearing from view. The Joplin branch of the Gulf railroad is laid upon it from near the junction south of Fort Scott to Farlington in Crawford county. Quantities of it have been crushed on Pawnee creek, 10 miles southwest of Fort Scott, by the Missouri, Kansas & Texas railway for ballast.

On the tributaries of the Marmaton, near the station of that name on the Missouri Pacific railway, are some fine exposures of this rock, but on the Marmaton itself two miles to the southwest of the station is to be seen one of the finest of these exposures. The river here cuts through it to its base upon the bituminous shales, leaving a bold overhanging cliff of 35 feet where the following section is exposed. Heavy layers on top and quantities of our coral—*Chetetes milliporaceous.* From the top of this rock 25 feet down there are several clay partings, and in those partings are pure veins of gypsum one-sixteenth to one-eighth of an inch in thickness. Below this the layers are somewhat evenly bedded.

It will be noticed that the coral common to this and the two members of the Fort Scott system is found in greatest abundance at the close of each limestone-forming period. The coral builders increased in numbers as the culminating points of those ancient reefs were reached. It will also be noticed that seemingly this coral began in the cement rock, reached its climax in the upper Oswego rock, and finally became extinct at the close of the period when the rock under consideration was finished.

In the neighborhood of the cliff already mentioned the Pawnee rock yields in good condition some few species of fossils, among

which are *Spirifer martinia; Athyris subtilita; Spirifirena kentuckiensis;* a ramose coral and columns of crinoidea. The Pawnee limestone disappears below the water of the Marmaton a mile and a half west of this fine exposure, but at once rises again, and just west of Redfield station, less than a mile farther on, it rises to the height of 20 feet above the river, and almost to the level of the railroad grade. Again it dips rapidly and soon disappears below the valley, so that at Bandera, a mile west of Redfield, it is only reached in the bottom of a well 20 feet deep. The Redfield anticlinal may have been partially formed by the excessive coral building, if the record of the well digger is to be relied upon, as he reports 52 feet of this rock at Redfield. The accompanying plate IV shows the entire strata so far as described.

The lateral extent of this rock is tolerably great. It extends to the southwest to beyond the Neosho river, and to the northeast to beyond the state line. Professor Haworth in chapter II has named it the Pawnee limestone.*

THE PLEASANTON SHALES.

Next in order above the Pawnee limestone we find 3 feet of clay shales underlying 6 to 10 inches of coal, which in turn is capped by a very dark, hard, silicious limestone 18 inches thick. Resting upon this lies a heavy deposit of arenaceous shales and sandstones. We could nowhere measure their entire thickness, but at Bandera, one mile west of Redfield, they are at least 100 feet thick. They contain the celebrated Bandera, Gilfillan, and other quarries from whence flagging has been shipped to many of the states of the Union. Forty feet at least above the black silicious rock these flaggings begin at Bandera and continue up for 18 feet; then heavy sandstones and arenaceous shales 30 feet farther to the limestone above. Sixty-four feet of these shales are exposed less than a mile east of Redfield on the bank of the river in the lowest trough of the synclinal of the Pawnee limestone. The bed of the Marmaton here rests on the black rock which covers the coal seam.

The attention of the reader is here called to the fact that less than two miles away from Bandera these shales have almost entirely

* Swallow probably refers to this same limestone, and gives it the same name.

changed their nature. Here, instead of sandstones they are drab and blue argillaceous yet somewhat arenaceous shales. This would show how the nature of our shales may change in a short lateral distance, and accounts at once for the lack of persistency in our sandstones.

In the southern part of Bourbon county flagging of the same nature is found in these shales, on the divide between the Drywood and Pawnee creeks. In the quarries flagging is taken out in slabs from 2 to 10 inches thick, and are what might be termed an argillaceous sandstone. The stone can be cut in any reasonable size, is quite firm and durable, and much of it as true to a uniform thickness as if put under a planing machine. The ripple and rill markings, with tracks of mollusk and crustaceans, are sometimes beautifully preserved on the surface of the slabs. Only fragmentary remains of the flora however are to be seen, the remains of animal life being nowhere found.

By the erosive forces of the past thin lenticular silicious, calciferous, and cherty layers in these shales were the sources in many places of the common gravels of the roadside and the farm. Occasionally among these gravels petrified wood occurs. In lateral extent this deposit extends to the southern limit of the county, and to the north trends away in a northeasterly direction, passing into Linn county.

Proceeding on upward in the geologic horizon we reach above this rich commercial deposit of sandstone another system of limestone about eight feet in thickness. At the top it is a loose rock, then a heavy bed, then in thin lamina, and at the base a conglomeritic or perhaps fucoidal rock. Two and a half miles west of Redfield it lies 27 feet above low-water mark in the Marmaton; but a mile and a half farther west it forms the bed and ford in the river, where an excellent exposure is to be seen. In it are to be found well preserved fossils, such as *Rhynchonella uta; Spirifer martinia; Reizia mormoni*, and *Spirifer plano-convexus*. Of the lateral extent of the rock we know but little, but from that little are inclined to think it is not very extensive.

The next deposit in the upward order is a heavy shale bed, which was not measured exactly, but judging from the railroad profile,

and basing our calculations on the general dip, cannot be far short of 150 feet. In its small outcrops it was found to be a clay but somewhat sandy shale, having here and there in it lenticular if not persistent layers of limestones and sandstones. Not knowing the limestones to be continuous for any great distance we therefore treat the whole as one system of shales. Fourteen feet above the last mentioned limestone there is a layer 2½ feet thick of thinly laminated limestone, which underlies the village of Uniontown. One mile west of Uniontown is a shallow cut on the railroad on which there has been exposed a thin layer of sandstone, and just below it was found 9 inches of hard blue limestone. We will note here that in this shale in the lower thin limestone deposit we found the last specimen observed of the characteristic coal fossil, *Chonetes mesoloba*, which fact has been used to determine the location of the division line of the Coal Measures. The whole of these shales lying between the Pawnee limestone and the Erie limestone have been named the Pleasanton shales by Professor Haworth in chapter II.

THE ERIE LIMESTONE.

We have now reached a very interesting triple system of limestones which cap the hills in the western part of Bourbon county. They come first into view in the summits of the mounds south of Uniontown, and at the water tank on the railroad, three miles west of Uniontown and 23 from the state line, their base is seen in the railroad cut. Here the road leaves the valley of the Marmaton and passing a little to the west of north rapidly rises over these limestone systems until it reaches the sandy shales above at Bronson.

In detail these limestones are as follows: Beginning at the bottom of the series there is first a dark limestone 16 inches thick in two layers, and above it 3 feet of drab clay shale. Upon this lies 22 feet of unevenly and very heavily-bedded limestone, projecting from the sides of the ravines like unto turreted walls. Immediately above this is 7 feet of clay shale, then again 3 feet of evenly-bedded limestone in two layers, above which lies 4 feet of clay and bituminous shales. Again we come to 16 feet of limestone—the lower portion somewhat evenly bedded, the middle heavily bedded and near to the top brecciated, with few vertical seams—then the top

section a somewhat silicious limestone, diagonally laminated in places, like unto some of our sandstones, all standing out in many localities in bold relief along the ravines. Above this is 9 feet of somewhat argillaceous shale, and on these shale we again find a limestone 1½ feet thick, in two layers also evenly bedded. Above this again there is 3 feet of bituminous shale, and superincumbent on this is our third limestone 25 feet in thickness. The lower 20 feet of this last is a somewhat evenly-bedded white limestone with an occasional chert concretion buried in it, but the upper 5 feet is a very cherty rock, around the cherts of which there is much chalky matter. This chert forms a coarse gravel overlying the hills in the immediate neighborhood of its outcrop.

To understand matters here an explanation of the course of the Marmaton is necessary. Leaving Uniontown, the river heads towards the southwest until it enters Allen county, then it deflects rapidly towards the north to its sources northeast of Moran in Allen county. The railway, as we have stated, leaves it passing to the north towards Bronson station, up a small tributary while yet in Bourbon county. The county line is situated on the divide between this tributary and the headwaters of the Marmaton itself. Our triple limestone underlies all this divide, but rapidly dips toward the Marmaton on the west slope, and forms the bed of that stream for some distance. The valley of the river here was given direction by the eroding away of the yielding sandy shales which come next in geological sequence.

Passing from Bronson west we cross the Marmaton after entering Allen county, three miles from Bronson and two from Moran. The limestone does not appear on the railroad although on a down grade some little until the river is reached, but on an abandoned railway grade three or four miles to the south of Bronson a cropping of the two upper systems is to be seen, the lower of which is found near the bed of the river. Following this, towards the north here, it rises rapidly from the water for three-fourths of a mile, then dips and disappears below the hills. Passing over the Marmaton to its west bank, and up the stream two miles from this last mentioned outcrop, we came to the farm of Mr. McGlaughlin, section 8, township 25 north, range 21 east, where a well had been newly dug close

by the river. We found here the upper one of our triple system not far from the surface of the valley. It was known by its fossils and could not easily be mistaken. In fact sandstone quarries were immediately above it. Here also it had its cherty nature and well preserved organic remains.

We stop a moment to call attention to plate IV, on which this series of rocks is represented as it appears, and to the peculiar fact that below each system, and separated by a few feet of shale, is a twin series of even-bedded limestone. But it must be noted also that the even-bedded rocks are generally at the base of every system in the entire section. We also cannot pass over the many species of fine fossils found in the white limestone, or upper one of this triple system. At least 25 species were taken from it, among which were six *Productidae,* four *Spiriferidae,* two *Terebratulidae,* a Nautilus, a Pleurotomaria, an aviculopecten, an Edmondia, a Macrodon, and Bryozoans.

THE THAYER SHALES.

Above the triple limestone the Thayer shales come next, and are at least 100 feet thick, but at no place could satisfactory measurements be taken with the instruments at hand. On Mr. McGlaughlin's place the lower sections of this shale bed yielded a good quality of sandstone for building, although not in heavy layers. At its summit rests a bituminous shale bed 4 feet thick, but no coal was reported from it.

IOLA LIMESTONE.

At Moran the highest point on the railroad was reached. The town is on the divide between the tributaries of the Missouri and the Arkansas rivers, and it is said that the waters falling on the east end of the depot seek the Missouri outlet to the Mississippi and those on the west the Arkansas. The town is built immediately on the eastern outcrop of what is known as the Iola "marble." This limestone, for such it is, was easily traced from Moran to the place whence it derives its name, a distance of 13 miles. At Moran 20 feet of it was found in wells. In localities between these stations the surface erosions in creek beds have left but a few feet of it, such

as on the farm of Mr. Parke, where but 6 feet of it remains. The westward dip in the 13 miles is about 170 feet, or 13 feet to the mile. As this limestone is described at length by Mr. Adams in chapter I, and by Professor Haworth in succeeding chapters, nothing further need be added here.

THE CARLYLE LIMESTONE.

Above the Iola limestone a monument standing south of Iola on Elm creek, in the shape of a circular mound, will now tell us what comes next in the upward geologic scale. At its base upon the Iola rock rests 15 feet of blue shales, buff limestones, and calcareous shales, quite fossiliferous, containing *Pautilus occidentales, Nautilus ferratus* (?) *Retzia mormoni*, etc. Above this are 53 feet of arenaceous and micaceous clay shales, and capping the mound is 6 feet of unevenly-bedded limestone, adapted for rough mason work. Much of it has been removed by the quarrymen. This rock with its numerous fossils was a bonanza to me some four years ago when I first visited it. All the common fossils in the lists already mentioned were found here. This limestone has already been named the Carlyle limestone. Westward from Iola the line of our section carries us to Yates Center. Between these two points limestone is observable at but two places. The first is on the hilltops west of the Neosho river where a limestone system of moderate proportions is found which quite evidently is the Carlyle limestone. Still farther west, about half way between Piqua and Yates Center, either the same or a second limestone is found on the west side of ——— creek. It was not yet definitely determined whether this is another exposure of the Carlyle limestone, but quite possibly it is. From here to Yates Center the surface rises quite rapidly, and the roadbed passes onto a high, sandy plateau which is the southwestern extension of the sandstone area in the environs of Burlington. To the west of Yates Center a few miles without any perceptible change in the topographic features the Burlington limestone is reached, which takes us to the end of our section.

CHAPTER V.

A GEOLOGIC SECTION FROM STATE LINE, OPPOSITE BOICOURT, TO ALMA, PRINCIPALLY ALONG THE OSAGE RIVER.

BY JOHN G. HALL.

This section starts on the eastern state line opposite a point about half way between Boicourt and Pleasanton, where the Osage river crosses the eastern line of Kansas into Missouri. From here it extends in a general northwesterly direction up the valley of the Osage river to its source, and thence across the divide into Mill creek valley, Alma being its terminus. It passes through portions of Miami, Franklin, Linn, Osage and Wabaunsee counties, and covers a distance of about 116 miles. Like all other sections within the Coal Measures of Kansas the rocks along it consist of limestone, sandstone and shales, the latter predominating in amount.

CONDITIONS NEAR THE STATE LINE.

Immediately at the state line the lowermost formation exposed to view is a heavy bed of shales which, being an eastward extension of the shales so abundant in the vicinity of Pleasanton, may be readily correlated with the Pleasanton shales. The base of these shales is not exposed at the state line, so their total thickness here could not be determined, but presumably they are little different from that at Pleasanton and Boicourt, which is given in chapter II as exceeding

200 feet. Above the Pleasanton shales limestones occur from the state line to Boicourt substantially the same as at the latter place. As these have been described in considerable detail by Professor Haworth in chapter II, there is no necessity of repeating their description here. The peculiar topographic features of the country, however, may well be noticed, features which are dependent conjointly upon the heavy shale beds beneath and the protective limestone caps. The Osage has cut its channel through and far into the shales. In the vicinity of Osawatomie the westward dip of the limestones brings them so low that the bluffs are scarcely 100 feet high. But as the limestones rise to the east, and the stream descends in the same direction, the bluffs on each side of the river gradually become higher, until at La Cygne and Boicourt they are nearly 200 feet high. The Pleasanton shales decay rapidly and with great ease; the limestones above are persistent and strongly resist disintegration. In this way the sides or walls of the bluffs are steep, and sometimes are yielding so rapidly that vegetation cannot get a foothold. Sometimes also circular mounds are to be observed standing out in the broad valley entirely separated from the greater land bodies. They usually retain the limestone covering, and their sides are in every respect similar to the faces of the bluffs just mentioned.

The valley of the Osage river varies somewhat in width, but is from two to four miles wide. The stream itself meanders greatly within this valley, but the bluff lines approximate as great a degree of regularity as is usual for the bluffs of other rivers. The lateral tributaries entering the river at different places have cut their channel to a depth equal to that of the Osage river itself, and have similar bluffs bounding their valleys, the latter in some instances almost equal in width to the valley of the Osage river. This is well illustrated by Sugar creek. Its depth is equal to that of the river itself; the width of the valley is nearly three miles, and it is bounded on both sides from Boicourt to Blue Mound by bluffs equalling if not surpassing those of the Osage river.

THE IOLA LIMESTONE.

As was shown in chapter II the uppermost of the limestone at La Cygne is the Iola limestone. From La Cygne it passes to the northward to Fontana and from Fontana dips slightly to the northwest, covering the surface of the country to beyond Osawatomie. At this place it covers the surface of the hill on which the insane asylum rests. Westward it can be seen all over the Pottawatomie valley to the vicinity of Lane, near which place it disappears beneath the Pottawatomie river. Along the Osage river its westwardly dip and the general rise of the surface cause it to continuously occupy relatively lower positions until finally it passes downward out of sight on the uplands in the vicinity of O'Brien, four miles to the west of Osawatomie, but it can be seen along the bluffs and the river valley much farther.

THE GARNETT LIMESTONE.

Just above the Iola limestone is a bed of shale known as the Lane shales, which is about 90 feet thick. These shales are of a light buff color shading in the lower half to a bluish gray, and in structure they are almost homogeneous, that is, they are of the same consistency throughout their entire thickness. After losing sight of the Iola limestone, four miles to the west of Osawatomie, and having passed over the Lane shales two new systems make their appearance simultaneously. These two systems are with difficulty separated when they first come into view, owing to the thinness of the bed of shales which lies between them. It is only 12 feet thick, and has in it a great many small shell-like pieces of limestone, so that when exposed to the weather these are brought out so prominently they give the appearance of a continuous system of limestone. These two systems are called the Garnett limestones. The lower one is only 6 feet thick, while the upper one at its first appearance is only a foot to 18 inches, but gradually thickens as it extends to the west until it attains a maximum thickness of 30 feet. The upper Garnett limestone can be easily traced to Ottawa, at which place it is exposed on the north bank of the Marais des Cygnes river, while the lower one cannot be traced all the way but it is found in the bottom of the river underneath the wagon bridge that

crosses it on Main street. At the crossing of the railroad and the county line between Miami and Franklin counties the Iola limestone lies five feet below the railroad track and the lower one of the Garnett limestones covers the top of the hills 50 feet above the track. In the uppermost of the Garnett limestones occur the Lane quarries, famous throughout the state for the so-called "Lane marble," which is a hard, gray limestone that is capable of taking a very good polish. At this place the limestone reaches a thickness of 45 or 50 feet, a local thickening where the conditions for the same were especially favorable. Here the dip of some of them is most extraordinary, being in some instances a foot or even 18 inches in a hundred feet distance.

THE LAWRENCE SHALES.

Passing west from Ottawa one of the heaviest beds of shales in the whole section is reached. It corresponds with the heavy bed that is found so extensively around Lawrence, and has been called the Lawrence shales. They are particularly characterized by the large amount of sandstone they contain and the irregularity with which it occurs. Nowhere does it reach a high degree of perfection as sandstone, but frequently grades back and forth from a soft, friable sand rock into arenaceous shales. Almost every stream that has cut a deep channel into the shales has bluffs of such sandstone here and there throughout its course. A prominent one of these occurs on the south bank of the Marais des Cygnes river, about 10 miles west of Ottawa, in the vicinity of Pomona. Here above the heavy bed of sandstone the formations bear good evidence of having been produced in marginal areas, or shallow water lagoons, for the shales pass into sandstone and back into soft shales with great frequency. The upper sandstone is hard, and has an appearance very like limestone. The surfaces of the different layers are covered with ripple marks and wave marks, which are made more apparent by weathering. Some of the sandy shales are quite firm and hard, but are so perfectly laminated that they cleave with great perfection parallel to the bedding planes. Upon weathering, however, they produce very irregular surfaces, the ripple marks being remarkably pronounced and exceedingly intense.

The Lawrence shales, like most heavy shale beds in the state, have in them seams of coal which are of so good a quality that they are mined and put upon the market. The principal mines are located in Franklin county, the coal from which in commerce is known as the "Franklin county coal." It is placed upon the markets of Ottawa and neighboring towns, and to a limited extent freighted to other parts of the state. Near the outcroppings of the coal seams the mining is conducted by the ordinary "stripping" process, but in a few localities, particularly near Pomona, the shafting method is used. The Franklin county coal seams vary in thickness from a few inches to a maximum of 2 feet. It is found at different horizons within the shales, but the heaviest veins are found near their base. To the north of the limits of this section, in Douglas county, coal also is found in the Lawrence shales, the details about which are given in chapter VII.

Along the line of this section the Lawrence shales are considerably over 100 feet thick, so that their southeastern limit produces strong physiographic features. The protection of the overlying limestone in connection with the soft character of the shales in certain localities produce exceedingly rugged bluffs, while in other places the interbedded sandstone is sufficiently abundant to resist erosion to so great an extent that almost no escarpments are produced. Occasionally a circular or oblong mound exists a few miles to the southeast, having been in some way preserved while the remainder of the surrounding material was worn away in the production of the valleys.

THE OREAD LIMESTONE.

Above the Lawrence shales two systems of limestone are found, the Oread limestone, separated from each other by from 12 to 15 feet of shale. The lower of the two is about 15 feet thick; the upper one when first found is eroded away almost to a thin edge, but soon thickens to 18 or 20 feet.

SYSTEMS ABOVE THE OREAD LIMESTONE.

The first limestone system above the Oread limestone appears 10 miles west of Ottawa, and is 4 feet thick covering a shale bed 50

feet thick. The general appearance of the limestone is much like that of the Oread limestone and would make good building stone. The shales below this limestone are buff in color and generally soft, and hence yield to the weathering agents quite readily, but sometimes they turn into a brown sandy shale which is very coarse, instead of being composed of the usual fine particles that generally make up the shales.

Following up the river another limestone, No. 2, is reached a mile west of Quenemo, and is 5 feet thick, covering a shale bed of 20 feet. It is composed of two layers of almost equal thickness and is of a grayish yellow color and quite hard. The shale bed has so many thin layers of sandstone, which are made up almost entirely of silica, that it wears away nearly as slowly as the limestones. The layers of silicious sandstone are none of them more than 2 or 3 inches thick, while most of them do not exceed half an inch..

Six miles to the northwest of Quenemo system No. 3 crops out, which is 10 feet thick, the upper 4 feet of which is brown in color, while the rest is almost white. The whitish portion contains one layer about a foot thick which is composed of fossil fusilina, the shells of which are about the size and shape of a medium-sized grain of wheat.

THE OSAGE CITY SHALES, COAL AND LIMESTONE.

Six miles southeast of Burlingame system No. 4 crops out, but can only be traced a short distance until it is lost to sight. It is 15 feet thick, and corresponds so closely with the one found over the coal at Burlingame both in thickness and general structure that there can be little doubt but that it is the same system. It is 60 feet above No. 3, and is of a grayish white color. It is very soft, and therefore easily worked, but not used much on account of its softness.

The coal found at Burlingame is from 75 to 90 feet below the surface of the ground, depending on the position of the shaft. There is a broad almost level strip of country extending over nearly the whole of Osage county, underneath which the coal is found. The coal varies in thickness from 18 inches to 3 feet. It is mined at Osage City, Scranton, Burlingame, and Peterton, and formerly

was mined at Carbondale, but these mines have not been worked for some time. The whole country is dotted with coal shafts, some of which are worked only for private use, while the majority are worked and the coal put upon the market.

THE BURLINGAME LIMESTONE.

Just west of Burlingame system No. 5 makes its first appearance. It is 8 feet thick, is brown in color, shelly in character and covers the third and last heavy bed of shales in this section. The shale bed is 150 or 200 feet thick, and throughout it are found thin beds of limestone which tend to cause the shales to resist erosion. Here, as with all other thick beds of shale, are a number of isolated mounds which are covered with limestone that corresponds in general so closely with that found on the main bluffs one cannot help believing they are the same system. These mounds are most numerous to the north of Burlingame, and differ in height from 50 to 125 feet. The most important one is about two miles from Burlingame and is 85 feet high, and covers an area of almost a square mile.

SYSTEMS ABOVE THE BURLINGAME SHALES.

Four miles west of Burlingame another limestone, No. 6, makes its appearance. It is 10 feet thick and 40 feet above No. 5. It has a dark yellow color where it has been exposed to the weather and breaks up into almost square blocks, due to the prevalence of vertical seams. The shale beds beginning with this one from now on to the end of the section are so thin and so similar and almost identical in character that no description of them seems necessary, except the one that occurs above the system that is known as the Cottonwood Falls rock, which will be described in its proper place.

The next system, No. 7, appears one mile northwest of Harveyville, and is 8 feet thick. It has a dark brownish yellow color, and when exposed to the weathering agents becomes quite shelly. The limestone can easily be traced to the northwest until it is covered by the next system.

No. 8 is seen on the northwest of Harveyville. It is of a grayish white color and is composed almost entirely of well-preserved

brachiopod shells, none of which are more than half an inch across. The system is only 3 feet thick and is 20 feet above No. 7.

After losing sight of No. 8 there appear three systems: No. 9, which is shown four miles southeast of Eskridge, and is only 2 feet thick; No. 10 appears one-fourth of a mile back from the edge of No. 9, and is 3 feet thick. The third of these systems is No. 11, and is only a foot thick, and is light gray in color. These three systems are all found in a rise of the ground of 150 feet.

One mile east of Eskridge system No. 12 makes its appearance. Its thickness could not be determined here, but the next higher one was traced across the hills into the Kansas river valley and the thickness of system No. 12 was found to be 15 feet, and was 20 feet above No. 11.

Just east of the railroad station at Eskridge system No. 13, which is known as the Cottonwood Falls rock, makes its first appearance. With the advent of this rock there comes in a change in the general character of the limestones. They become very white, and instead of breaking into small pieces when exposed to the weather they seem to wear away gradually and almost regularly, that is about equally in all parts. The system is 6 feet thick and has two layers of almost equal thickness and is used throughout the state for building purposes. In it there are three rows of flints which do not wear away as rapidly as the rest of the rock. It can easily be traced to Alma or the end of the section. Above it in the shale bed there are found an unusually great number of fossils, mostly brachiopods and a few short pieces of crinoid stems and a few spines of sea urchins. These fossils are all found in the lower six feet of a shale bed of 15 feet.

Above this system there are yet three others, the first of which, No. 14, is 3 feet thick and where exposed weathers white. The next system, No. 15, is 30 feet above No. 14, and weathers white the same as the preceding ones. The next and last system is No. 16, and can only be found on the tops of some of the highest points of the bluff. It is 20 feet above the last one and is 3 feet thick in one or two places. It weathers white with the exception of a number of very fine black specks. The last four systems can be traced from Eskridge to Alma because they are exposed on the sides of the precipitous bluffs.

CHAPTER VI.

A GEOLOGIC SECTION ALONG THE KANSAS RIVER FROM KANSAS CITY TO McFARLAND.

INCLUDING A SECTION ALONG MILL CREEK.

BY JOHN BENNETT.

For the beginning of this chapter, and as a part of it, the reader is referred to the description of the section at Kansas City as given in chapter II.

No. 8 of that section, known as the Bethany Falls limestone, of Broadhead, has a fine exposure in the face of the bluff which juts out into the state of Missouri a short distance and forms the great ridge between the Kansas river and Turkey creek. This heavy system soon disappears below the hills westward after leaving the Missouri state line. Of No. 7 the same could also be said, for it is soon covered in the slopes, chapter II, and appears but once more, just west of Turner.

No. 6, however, has several good exposures on both sides of the Kansas river to the west. At Argentine 10 feet of it has been exposed by the grading of a street. The top of the exposure here contains much of the characteristic black chert. Above the middle of the exposure is a 16-inch stratum of blue limestone, below which the rock is not as cherty as at the top. This blue stratum is the

cemetery wherein was buried the carapace of that large cephalopod, *Nautilus ponderosus*, several of which are in the State University museum, but which were taken from it at Turner, some three miles west. The second large exposure of this cherty rock was made by the Santa Fe railroad, at a cut one mile west of Turner, and six from the Missouri line. Here we find 11 feet of cherty limestone on top, then 4 feet of limestone with clay partings, then a clay parting of several inches, below which was 6 feet of fine grained dove colored and drab limestone, then a shale parting of a few inches, below which lay 9 feet of heavily-bedded limestone. Evidently Nos. 6 and 7 are together here. At Kansas City they are separated by but 4 feet of clay shales. In the correlation of the rocks of southeastern Kansas we could scarcely hesitate to say that the equivalent of this cherty system is found in the upper rocks of the Erie system of the Marmaton section, plate IV, east of Bronson. The cherty system is seen in the Muncie hills of Wyandotte county, where there are strong evidences of an anticlinal affecting all of the rock systems under consideration. That is to say, the rocks dip towards Kansas City from these bluffs to the eastward, and in the opposite direction westward in common with other strata in the Coal Measures of Kansas. After leaving the exposure at Turner and the Muncie hills little more is seen of this cherty system, and it soon disappears below the valley of the Kansas river.

The Oolite limestone, or No. 5, although it has many outcroppings in and around Kansas City and the Muncie bluffs, in which places it has been extensively quarried, is not often seen on the south side of the river westward. One mile west of Turner is an exposure above that of Nos. 6 and 7. Here but 9 feet appears, and the upper 3 feet only is oolitic, the lower part being an irregularly-bedded gray limestone. It comes down to the railroad grade just east of Holliday, where it was last seen. The oolitic part of the system has everywhere its abundant and well preserved characteristic fossils.

Next above this is No. 4, a fine grained gray limestone, retaining a uniform thickness of about 9 feet wherever found. It has been extensively quarried in and around Kansas City on account of its good building qualities, although generally not even bedded. In the Turner exposure it is separated from No. 5 by 12 feet of shales,

and has an exposure of 8 feet, the other foot being eroded away. At Holliday it has many croppings around the hills above the railroad tracks, and for some distance up the bluffs of Mill creek. At Bonner Springs, just north of Wilder, but on the opposite bank of the river, it is exposed between the Union Pacific railroad tracks and the river, and here has an abundance of *Campophyllum torquium*. This and the croppings at Wilder are the last seen of it.

SECTION AT TURNER.

To explain the conditions of Nos. 4, 5, 6, and 7, at exposures one mile west of Turner, we will here give the section at that place:

1st.—8 feet fine grained irregularly-bedded limestone.

2d.—12 feet gray, blue, and buff nodular shales.

3d.—9¼ feet oolitic and gray limestones.

4th.—18½ feet slope.

 11 feet black cherty limestone.

 3 inches clay parting.

5th.—6 feet fine grained dove colored and drab limestone.

 3 inches shales.

 9 feet heavy-bedded limestone.

6th.—6 inches clay parting.

7th.—9 inches laminated limestone.

8th.—3 inches buff shales.

9th.—1½ feet gray argillaceous limstone.

10th.—2 feet bituminous shales.

Above this comes the "large fossil" limestone, and although but 5 feet thick it is well marked on the sides of the bluffs in and around Kansas City on account of its firm character. It is last seen near Corning, on the north side of the river, and east of Cedar Junction two miles on the south side of the river. Below it in their proper places were found several specimens of the little rare fossil *Conularia crustula*, already mentioned. Nowhere however has this fossil been found in such abundance outside of the Kansas City bluffs as at this exposure east of Cedar Junction.

Again ascending through 25 feet of shale we come to No. 2, or the Iola limestone, the "heavy top rock" of Broadhead. At Kansas City, Mo., it forms the bold escarpment near the top of the bluffs

above the union depot and south of the Santa Fe railroad as far west as Argentine. It is found in the hilltops in Kansas City, Kas., and in the Muncie hilltops. Near the river just west of Argentine it has been eroded away, and is only found in the hills as they recede far to the south from the valley of the Kansas river. It again however approaches the valley before Holliday is reached and there forms the rough rocky face of the bluffs. West from Holliday it again recedes somewhat, but soon returns, and between Wilder and Cedar Junction forms the escarpment so plainly seen from the railroad all the way. At Argentine it thickens up to 32½ feet, and is extensively quarried for flux for the silver smelters of that town. The clay shales below it also thicken to 25 to 32 feet, as seen at the smelter rock crusher. Twelve feet down from its summit is 4½ feet of nodular rock separated by shaly and loose clays abounding in the common fossils of the Coal Measures. At the quarry east of Argentine a mile or so and at Fifth and Barnett streets in Wyandotte it has the same characteristics, also at a quarry opened between Edwardsville and Bonner Springs on the north side of the Kansas valley. At Cedar Junction and De Soto this heavy limestone system comes down to the level of the valley, but can nowhere be measured in its entire thickness at those places. Along the north side of the valley between Loring and Lenape it forms a cliff 100 feet high. There are good reasons for believing however that the system above coalesces with it here. At the Edwardsville quarry they are not united, but are separated by the same amount of drab shales—6 feet, as at Argentine. The valley of Bull creek separates the Edwardsville exposure from the Corning and Lenape cliff by about five miles, and therefore we are in ignorance of where they come together, if they do at all. At Argentine their combined thickness including the shale separation would be about 50 feet, but at the Corning and Lenape cliff there seems to be a solid system, measuring from the valley to its summit 100 feet, and we know not how much it passes below the valley. An interesting fact is worthy of note here. The very perceptible narrowing of the Kansas river valley at this locality is due undoubtedly to the stubborn resistance of this rock in the fluviatile erosions of past ages. On the north side this whole system with the system above

dips below the valley between Lenape and Linwood. The base of it is seen at Cedar Junction and the top section at De Soto. West of De Soto it dips under the valley, and where it disappears there seems to be a separation between it and the rock above, as indicated by benches and slopes along the hillsides. On Mill creek, between Olathe and Holliday, it has this same separating stratum of shale from the rock above, or our No. 1 of Kansas City, Mo., which we will now describe.

The arenaceous limestone, as has been said, retains its characteristics for some distance at least to the west. At the Edwardsville quarry it is well exposed, and between De Soto and Weaver, where it appears near the Santa Fe railroad, it seems to be a crumbling rock, although losing somewhat of its sandy nature. As has been hinted, the top of the Lenape cliff may be its equivalent.

We have now described all the important limestones as found in the Kansas City section with their disappearance to the west, the uppermost one going out of sight before Eudora is reached. That is to say that the very top rock at Twelfth street bluff, Kansas City, Mo., extends west some 25 miles before it disappears from view. The general dip in this distance would be about 6½ feet to the mile, as the railroad rises 60 feet in this distance and the rock strata falls about 160 feet. Our next limestone system first makes its appearance three miles to the west of the state line, at Argentine, and caps the highest point of the hills there (see Argentine section, figure 2, page 51). The slope here of 45 feet above the last-mentioned rock represents it and the shales which underlie it. We will provisionally call it the "Syntrialasma" limestone, on account of the abundance of this fossil in it wherever it is exposed at Linwood, Leavenworth county, or at Ottawa, Franklin county, or north of Olathe, Johnson county, or at Eudora in Douglas county. At Argentine the limestone at the top of the hill did not seem to have this fossil, leading me to think that it was a part of the system above the Syntrialasma rock. At Eudora there is but 5⅓ feet of shales between it and the limestone above, and the parting is not over 15 feet at the park north of Olathe and perhaps less than that at Ottawa. The "Syntrialasma" limestone at Eudora and Linwood is but 6 feet thick, while north of Olathe it is fully 13 feet. Sup-

posing this rock to be covered over in the slope of the Argentine section and that it was of the same thickness as its congener at Olathe then the 45-foot slope could be thus divided: Ascending there would be first 17 feet of shale then 13 feet of limestone (Syntrialasma rock) then 15 feet shales, thus reaching the limestone capping the hill, 3 feet of which has been left.

SECTION AT ARGENTINE.

We now give the complete section at Argentine. Beginning at on the top of the hill at the city water-tank there is:

1st.—3 feet of limestone.

2d.—45 feet covered slope which must contain the Syntrialasma limestone.

3d.—11⅓ feet arenaceous limestone.

4th.—6 feet blue clay and somewhat arenaceous shales.

5th.—32½ feet bluish gray, flesh colored and buff limestone—the Iola limestone.

6th.—35½ feet of buff, blue, and drab shales.

7th.—1½ feet limestone, in one layer.

8th.—1¾ feet buff clay shales.

9th.—3 feet gray limestone with calcite streaks.

10th.—8 inches ochery clays and blue shales.

11th.—8 inches gray limestone.

12th.—1¾ feet gray clay shales.

13th.—1 foot light drab limestone.

14th.—11¼ feet light drab clay shales.

15th.—1 foot chocolate colored, easily disintegrated limestone.

16th.—3⅓ feet gray shales.

17th.—7 feet gray limestone somewhat oolitic.

18th.—Clay shales 4 feet, then a slope of 40 feet.

19th.—3 inches limestone.

20th.—6 inches clay.

21st.—10 feet black cherty limestone.

The "Syntrialasma" limestone while it may be and undoubtedly is in the tops of the hills to some distance south of the Kansas river valley, yet it was not seen until Weaver was reached. Here it appears in the low bluffs, and midway between Weaver and Eudora

it comes down to the railroad cut and is well exposed. Here it is an even-bedded but brittle limestone 6 feet thick and lies on a bed of gray and drab shales with a foot or so of bituminous shales a little below its middle. On the north side of the valley three miles west of Linwood it has the same lithologic characteristics and is associated with like beds of shale. The upper layers of it are especially rich in well preserved fossils, of which *Syntrialasma hemiplicata* is most abundant. *Terebratula bovidens* come out of it in good condition and colored red, while *Syntrialasma* is a pure white. It also carries fine specimens of *Bryozoa* and *Productidae, Productus longispinus* being especially abundant, *Athyris subtilita, Spirifer cameratus, Spirifer martinia* and a *Chonetes* are among its organic remains.

The next limestone above it is 17 feet thick at Eudora and has been extensively quarried for ballast by the Santa Fe railroad. It is a rough rock both here and at Linwood, where it was also crushed by the Union Pacific company for ballast. It contains but few fossils here except the common forms. Just west of Eudora and up the Wakarusa towards Blue Mound it and its associate Syntrialasma rock dip out of sight. Before dismissing it however from our consideration we would call attention to the fact that immediately above the upper Eudora limestone there lies 3 feet of brown and somewhat calcified clay shales upon which lies 1½ feet of thinly laminated limestone all of which might be added to the 17-foot system below it. It may be added that the "Syntrialasma" rock and the first one above it constitute the Garnett limestone.

THE LAWRENCE SHALES.

We now come to a very heavy body of sandy and clay shales not less perhaps than 300 feet thick which have been called the Lawrence shales. The extensive valleys of the Kansas river and the Wakarusa have been excavated in them and the low hills in the neighborhood of these valleys are but the remnants of them. Just west of Fall Leaf station, on the north side of the river, the base of these shales assumes the form of a very firm sandstone which has considerable lateral extent, appearing in Blue Mound to the south of the river and among the hills farther to the south. In the bed of

the river under the Lawrence dam there is a limestone nowhere else seen, unless it should prove to be a part of the Eudora system. The general dip, as has been shown from Kansas City for twenty-five miles west, is 6½ feet to the mile. This if continued would put the very uppermost section of the upper Eudora rock at least 40 feet below the railroad grade at Lawrence—the distance from the Eudora outcrop and place measured being nine miles in a directly east and west line. But the dip west of Lawrence is greater than east which change if begun before reaching Lawrence would put the Eudora rocks much farther below the city; and that seems to be a fact, as indicated by the record of a well-boring at Lawrence, as shown in plate VI. Above this limestone there is another thin limestone in the system of shales, perhaps not far from their middle, which has many croppings among the low hills east and south of Lawrence, and also in the country north of the river valley. It appears by the Santa Fe railroad track two miles northwest of Lawrence where it dips under the valley. Below it coal has been taken out in several localities. About 60 feet below the top of the Lawrence shales is another layer of coal, neither of which is very persistent, although in places each is of some value. The coal varies from 1 to 16 inches in thickness. Dark shales which undoubtedly grade into coal in places are also found near the summit of this shale bed.

THE OREAD LIMESTONE.

Ascending the hill at the State University we find near its summit a limestone system 12 feet thick which on exposure weathers dark buff. Between it and another heavy system above are some 16 feet of shale, near the middle of which lies a thin limestone stratum not often seen west of Lawrence, but assuming some importance in the high country north in Jefferson and Leavenworth counties. These systems have been named the Oread limestones in honor of Mount Oread, the hill on which our State University stands. To distinguish them we will call them the upper and lower Oread.

The lower Oread limestone disappears before reaching Lecompton, passing beneath low water mark at that place. It carries an abundance of the fossil *Fusulina cylendrica* and was the first rock in

the section to contain in quantities this little Rhizopod. ***Athyris subtilita, Cyathaxonia distorta*** and Crinoid columns are among its fossils.

The upper Oread is largely developed and exposed at Lecompton where it has been extensively quarried for ballast by the Santa Fe company. It weathers dark brown like its associate, and all the limestones above it as far west as Topeka. The shales between the two Oread limestones retain their uniform thickness wherever seen, and are generally buff and olive clay chales. At Lecompton the upper Oread limestone is 22½ feet thick, capable of subdivision as follows: Resting at its base are a few feet of bituminous shales, then 12 feet of heavy-bedded rock, the middle 2 feet of which is very cherty. Above this lies 1 foot of blue clay shales; then 6 feet of shelly nodular limestone with heavy clay partings abounding in well preserved fossils, and this again is capped by an even stratum 1½ feet thick, separated from two layers above by 4 inches of clay, the top layers being 1¾ feet thick. On its summit lies a glacial gravel conglomerated by the cementing process of lime infiltration.

This limestone is a very interesting one to the paleontologist on account of its profuse and varied fossils. For that reason we will give here a complete list of all obtained from it: *Fusulina cylindrica*, two *Bryozans*, *Fistulipora nodulifera*, *Chaetetes* (?), two *Crinoids*, *Archaeocidaris* (?), *Cyathaxonia distorta*, *Athyris subtilita*, *Spirifer cameratus*, *Spirifer lineatus*, *Spirifirena kentuckiensis*, *Productus prattenianus*, *Productus symmetricus*, *Productus americanus*, *Productus pertenuis*, *Productus costatus*, *Productus punctatus*, *Productus nebrascensis*, *Productus longispinus*, *Derbya bennetti*, *Derbya broadheadi*, *Meekella striato-costata*, *Syntrialasma hemiplicata*, *Terebratula bovidens*, *Retzia mormoni*, *Nucula ventricosa*, *Chonetes granulifera*, *Schizodus wheeleri*, *Chaenomya leavenworthensis*, *Allorisma subcuniata*, *Allorisma granosa*, *Pinna peracuta*, *Edmondia* (?), *Rhynchonella uta*, *Chaenocardia* (?), *Monoptera* (?), *Macrodon* (?), *Aviculopecten* (?), *Bellerophon crassus*, *Bellerophon* (?), two species of *Nautilidae*, *Enomphalus rugosus*, *Orthis carbonaria*, *Campophyllum torquium*, *Pleurotomaria*, two species, a branching coral, and other unidentified forms. At least 50 species were taken here in the quarry just east of the rail-

road station. This extremely interesting limestone is last seen about three miles west of Lecompton, where it disappears under the river valley, and takes with it its precious museum from which we regret to part company.

Above the last mentioned limestone lies a heavy shale deposit at least 97 feet thick at Lecompton. The lower 65 feet of this is a clay shale, then 16 feet of arenaceous shale, parted by a thin stratum of arenaceous limestone, then 5 feet of sand rock, above which lies 11 feet of sandy buff shales.

THE LECOMPTON LIMESTONE.

Capping the hills around Lecompton is a 5-foot limestone in two layers, which we will provisionally name the "Fusulina" limestone, not that it alone bears that fossil, but because of the abundance of Fusulina in it. It is the lower of another triple system of limestones, the members of which are separated by a few feet of shale, and which retain this order as far as observed to the west. Above the "Fusulina" stratum are 5½ feet of clay shales, then 1¼ feet of blue limestone which weathers dark buff like all its associate strata. Above this are 4 feet of shales having a bituminous streak in the middle, then 10 feet of light gray, easily disintegrated limestone. This group may be called the Lecompton limestone, on account of their outcropping being near Lecompton. At Spencer, six miles west of Lecompton, the upper of the series finally disappears below the alluvial soils of the valley.

The fossils of the Lecompton series merit little attention except the *Fusulina* of the lower bed. In the top of a hill at Lecompton, where the lower member was greatly weathered, this little foraminiferous rhizopod lay in such profusion that it looked as though some farmer had emptied his wheat sack in the soils.

Passing westward from Lecompton a slight difficulty was encountered in the correct understanding of the strata. The hills around Spencer were so covered with glacial material that the strata were principally concealed. One limestone was visible on a hilltop a mile south of Spencer, and which seems to dip westward and reach a relatively low position at Tecumseh. Two other limestones are also visible at Tecumseh, one of which forms quite a

riffle in the river, and the other of which lies below it and forms a floor to the river for some miles below. The glacial material is so abundant between Tecumseh and Spencer that an error might easily be made in the correlations, but it seems that the section above the Lecompton series is as follows, counting upwards: First the thin layer in the bed of the river below the riffle about 40 feet above the Lecompton system; then 4 feet of shales, and then the riffle rock 3 or 4 feet thick; then 25 feet of buff clay shales with small lenticular bodies of limestone throughout it; and then 2 feet of blue clay shales immediately under the top rock at Spencer above mentioned.

THE DEER CREEK SYSTEM.

We now come to what we may call the Deer creek systems, the bottom one of which may be the limestone seen in the top of the hill at Spencer, and is seen at a few places southeast of Tecumseh. The Deer creek exposure presents the following section, passing upwards:

First, 6 feet of fossiliferous unevenly-bedded limestone which was overlaid by 10 feet of shales, then a single-bedded limestone 2 feet, then 4 feet of drab and blue shales, and again 4½ feet of limestone. These limestones were scarcely seen excepting in the Deer creek exposures. They disappear altogether two miles or so east of Topeka. But above them in the tops of the hills, and separated by about 60 feet of slopes, are remnants of the system above, or the Topeka limestones.

The organic remains were well preserved in the Deer creek system, and the following genera and species were noted: *Productus altonensis* ? (might be young of americana) were especially abundant. *Bellerophon crassus* was found here.

THE TOPEKA LIMESTONE.

Coming now to the Topeka limestones, we find a quadruple series. In an exposure a mile east and a mile south of Topeka there is a showing of the upper section of the underlying shales. About 6½ feet below the top of the underlying shales a fairly good building sandstone is reached which is 3 feet thick. The lower limestone of the Topeka system is 6 feet thick, and is blue but weathers dark buff.

Above it is a foot and a half of blue shales, then above that 5 feet 8 inches of blue and brown limestone having a cherty layer near the top. Above this comes 2 feet of buff shales, and then again limestone $1\frac{1}{2}$ feet thick, above which are 3 feet of drab shales, which are again capped by 2 feet of limestone. The city of Topeka rests mainly above the cherty bed or second limestone in the series, yet here and there are fragments of the third or thinnest layer in place. The cherty bed has been extensively quarried by the builders of the city in the past and quarries are now being operated near Shunganunga creek in the south part of the city. The Santa Fe and Missouri Pacific railroads have made a few exposures in the two upper limestones of the series just south of the city. In the various quarries a good opportunity was given to study the paleontology of this quadruple series. The fossils collected were: *Fusulina cylendrica, Fistulipora nodulifera*, *Rhombopora lepidodendroides*, *Chaetetes* and a romose unknown form of *Chaetetes*, *Archaeocidaris* ———, *Zeacrinus mucrospinus* and *Zeacrinus acanthophorus*, *Fenestella* ———, *Chonetes granulifera*, *Productus punctatus*, *Productus longispinus*, *Productus costatus*, *Productus prattenianus*, *Athyris subtilita*, *Spirifer cameratus*, *Streptorhynchus crassus*, *Terebratula bovidens*, *Retzia mormoni*, *Bellerophon carbonarius.*

The shales above the Topeka limestone could nowhere be accurately measured. At the brick-yard, three miles west of Kansas avenue, in Topeka, 28 feet of the upper part of the shales are exposed, and in a well close by we were told that 20 feet more had been penetrated before reaching the Topeka limestone. This would make them 48 feet thick, which we had good reasons for thinking was about correct. At the top of the shale lies 11 inches of coal, which has been mined in many places just west of Topeka, and which may be called the Topeka coal. Above it lies $2\frac{1}{2}$ feet of clay shales and then 2 feet of argillaceous limestone, then 6 feet more of shale and again 2 feet of gray limestone. These limestones although thin were persistent for several miles to the west, where they and the underlying coal disappeared under the valley. The only fossils of any importance in this double system was *chonetes granulifera*, *Fusilina cylendrica*, a productidae, and Crinoid columns.

THE OSAGE SHALES AND COAL.

Four miles west of Topeka a section exposed in the railroad cut shows 26 feet of shales above the limestone system just described, and above them is a hard band of sand rock 2 feet thick which held its place until Lee's creek was reached, a mile and a half farther west. Beyond the creek at the sugar-works it was not seen. At the sugar-works, six miles west of Topeka, the coal and limestones above mentioned were all under the valley. Here the slope to the next limestone above was 91 feet from the Rock Island railway track, all of which seemed to be shales, but the exact thickness of the shale below the track could not be told. A reasonable approximation would put it at 25 feet, making a whole bed of 116 feet.

At the summit of the last mentioned shale there is a foot of coal, and immediately above it 2½ feet of limestone. It is quite probable that this is the equivalent of the Osage coal, as it corresponds with it in general stratigraphic position. The fossils of this thin limestone are *Chonetes granulifera*, *Spirifer cameratus*, and *Crinoid* columns. Above this limestone is 30 feet of clay shales and then 6 feet of limestone from which stone was obtained for the erection of the main building of the sugar-works plant.

A mile west of the sugar-works an exposure shows 21 feet of shale above the sugar-works limestone, and above the shale 5 feet of limestone. Three miles west of Valencia the sugar-works limestone disappears below the valley and is in the bed of the Kansas river a mile or so farther on at Willard on the Wabaunsee county line. At Willard the limestone above this thins out somewhat and becomes a good building stone blue in color on fresh surfaces. The fossils of the sugar-works limestone are *Allorisma subcuniata*, *Meekella striato-costata*, *Productus pertenuis*, *Productus semireticulatus*, *Crinoid columns*, a branching coral and a *Bryozoan*, *Bellorophon carbonaria*, and *Myalina recurvirostris*.

At Willard was met a change in the nature of the limestones. From Lawrence to this point all of them generally weather dark yellow, but here at Willard, on the borders of Wabaunsee county, the limestones change to buff and weather quite a dirty yellow. At Willard about 25 feet above the blue ledge the first buff lime-

stone comes in. It is but 2½ feet thick and in places it is literally filled with a robust form of *Fusulina. Productus semireticulatus*, spines of the Echinoids, *Meekella striato-costata* and a Bellorophon were also found in this limestone.

A sloping hillside—probably shale—of 50 or 60 feet brought us up to another limestone system 8 feet thick which abounds in the robust form of Fusulina, and is a yellow rock like the one before it. It also contains a large form of *Lophophyllum proliferum*. It disappears under the bed of Mill creek south of Maple Hill, and has a fine perpendicular exposure a mile or so east of Maple Hill on Mill creek. Above it and separated by 10 feet of arenaceous shale is a thin limestone stratum 1 foot thick. Then above that are 50 feet of sandy shales overlaid by 2½ feet more of the yellow limestone which is largely made up of our little *Fusulina cylendrica*. This limestone forms the flat hills just east of Maple Hill on Mill creek and the low benches west of that village.

BUFFALO MOUND.

Three miles southwest from Maple Hill is Buffalo Mound, over 300 feet high above the valley. Making our last mentioned or the fourth yellow rock in the ascending series our base at Buffalo Mound, the section would be as follows, counting downwards from the top:

1st.—Top of Buffalo Mound a fragment of the Cottonwood Falls limestone.

2d.—28 feet slope, probably all shale.

3d.—Thin seam of limestone.

4th.—42 feet slope, probably shale.

5th.—Thick limestone system, but could not be measured exactly; probably 6 feet.

6th.—26 feet slope, probably shale.

7th.—Thin limestone.

8th.—16 feet slope, probably shale.

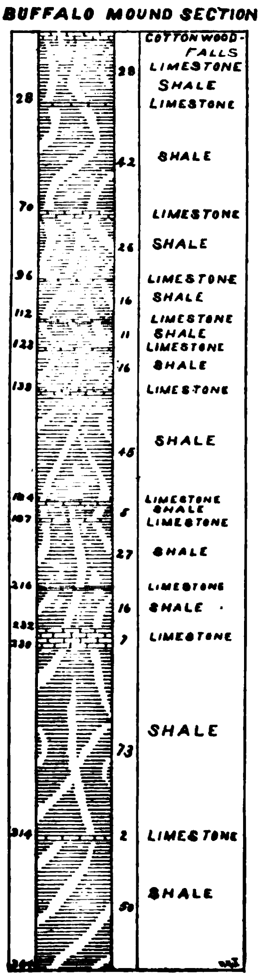
9th.—Thin limestone.

10th.—11 feet slope.

11th.—Thin limestone.

12th.—16 feet slope, probably shale.

13th.—Thick stratum of limestone (many crinoids).


BUFFALO MOUND SECTION
COTTONWOOD-FALLS LIMESTONE
28
SHALE
28
LIMESTONE
SHALE
42
70
LIMESTONE
SHALE
26
96
LIMESTONE
SHALE
16
112
LIMESTONE
11
SHALE
123
LIMESTONE
SHALE
16
138
LIMESTONE
SHALE
45
184
LIMESTONE
SHALE
5
187
LIMESTONE
SHALE
27
216
LIMESTONE
SHALE
16
232
LIMESTONE
7
SHALE
73
314
2
LIMESTONE
SHALE
50

14th.—45 feet slope, probably principally shale.

15th.—Thin seam limestone.

16th.— 5 feet slope.

17th.— Thin seam limestone.

18th.—27 feet slope, principally shale.

19th.—Thin seam limestone.

20th.—16 feet slope, probably shale.

21st.—7 or 8 feet of limestone in two systems, close together.

22d.—73 feet slope, probably mostly shale.

23d.—Fourth yellow limestone system.

24th.—50 feet arenaceous shale, partly in valley below.

All these limestones have a light yellow color, becoming lighter toward the top. There is however one exception, and that is No. 13 of last section, which is a gray limestone holding many small crinoid columns. South of Paxico some five miles on Snokomo creek is a quarry in this limestone. Here it is in two even-bedded layers, and can be cut into pieces from five to eight feet long and any desirable width. It is said that it was used to a limited extent in the construction of the state-house at Topeka. In the shales above we gathered an abundance of very fine fossils on a creek farther to the west and just south of McFarland station. Here *Fusulina cylendrica* could be gathered by the handful; *Chonetes granulifera* were plenty, as were also the plates, spines and columns of *Zeacrinus mucrospinus.* Being hurried in this part of our Survey we had little time for collecting fossils. Evidently these rocks and shales are rich in the fauna of the upper Coal Measures.

Comparison of Buffalo Hill Section with Meek and Hayden's Section.

On comparing the above section at Buffalo Mound with that made of it by Meek and Hayden, in the summer of 1858,* they note the prominent limestone beds of the above section, and in the order in which we have them, with the exception that they give greater elevation to the hill and correspondingly greater distances between the heavier beds of limestone. Our No. 13 they place at 160 feet down from the summit of the hill, while our measures are but

*Pro. Acad. Nat. Sci., Philadelphia, vol. 11, p. 12.

145 feet. We can scarcely be mistaken in the fact that the same limestone stratum is considered here, for it is the only gray limestone in the hill, and has its many columns of *Crinoids*, which mark it well paleontologically. Then our No. 21 and their No. 2 agree not only in characteristics but in being placed equidistant down from the numbers last mentioned respectively. Below this again our No. 23 and their No. 17 would seem to be equivalents, except that their No. 17 is 27 feet too low down, while their No. 12 would be about the right horizon geologically for our No. 23. We must admit, however, that the task of correlating these sections is a difficult task, from the fact that so many thin strata of limestone exist in the shales of this region, and each of them standing out more prominently in one place than another it would be an easy matter to give note to any one stratum which might appear in one place and not in another. Their section was evidently made on the north side of the hill, while our's was made on the long eastern slope. In the hilltop where they make a slope of 160 feet, we observed at least four thin strata and one 6-foot ledge. At the base of the hill they in turn observed several thin strata not observed by us.

Before reaching Alma four other limestone systems are to be seen in the high country east of that city. We can but mention them here about as follows: First, above the Cottonwood Falls limestone which is considerably thickened in the bold escarpment east of Alma there is a 45-foot slope, then a limestone, then 30 feet more of slope and again a limestone, above which 15 feet more of slope brings us another limestone, and then 20 feet to the limestone capping the hills. For want of time these latter limestone systems did not receive a critical examination.

GENERAL REMARKS ON THE STRATIGRAPHY OF THE SECTION.

In reviewing the foregoing section a number of interesting points may be noted. At Kansas City the section is more than half limestone, and different limestone systems are very heavy, one measuring 30 feet in thickness, and increasing to much more in places. In the whole area east of Topeka we have four limestone systems that measure 20 feet or more. Westward the limestones become much thinner, and constitute a correspondingly smaller proportion of the

section. From the base of the section at Kansas City to the base of the Lawrence shales we have about 300 feet which is fully one-half limestone. From the base of the Lawrence shales to the top of the Topeka limestone the total thickness is about 641 feet of which only 83 is limestone, giving a ratio of $1:6\frac{2}{3}$. West of Topeka to the Cottonwood Falls limestone we have a total thickness of about 760 feet with only 60 feet of limestone, or $1:11\frac{2}{3}$. Covering the whole of the section we find a total thickness below the top of the Cottonwood Falls limestone of about 1,700 feet with a little less than 300 feet of limestone, or a ratio of limestone to shale and sandstone of about $1:4\frac{2}{3}$. By adding to this section the thickness of the Coal Measures at Kansas City, as shown in plate II, a thickness of about 700 feet, we have a total thickness of the Coal Measure clays on the Kansas river below the Cottonwood Falls limestone of about 2,400 feet, of which about 375 feet is limestone and 2,025 feet shale and sandstone, giving a ratio of limestone to shale of 1:5 2-5.*

The color and texture of the limestone also gradually change to the west. In the east the color is bluish on fresh surfaces and dark buff when weathered; to the west it becomes a light buff to a light cream, and almost white. To the east the texture is firm, to the west it is much more open and porous.

ADDENDUM:

A Section from Manhattan to Abilene. By Geo. I. Adams.

In completing this section up the Kansas and Smoky Hill rivers to the limit of the Dakota there is little to present which has not been already described by earlier writers. Meek and Hayden, Swallow, St. John, and later Hay and Prosser have described the section in whole or in part, and Prosser has reviewed the earlier writings and compared them with each other and with the conditions as he found them.* The following section at Manhattan is taken from Prosser:†

---

*Since the above was written by Mr. Bennett, the records of the Topeka and McFarland wells have been obtained, which show that the above estimates of thickness are too small.—E. H

* Bul. Geol. Soc. Am., vol. 6, pp. 29-54.

† *Ib.*, p. 33.

Section at Manhattan. (After Prosser.)

RESERVOIR LEVEL.

	Feet.
6.—Covered slope on Blue mount. At this horizon yellow shales containing plenty of fossils are exposed on mount Prospect, in the Uhlrich quarries up Wild Cat creek and at numerous other places about Manhattan	10=215
5.—Manhattan stone—a light yellowish gray, massive limestone containing a considerable amount of chert, and in the upper part great numbers of *Fusulina cylindrica*, Fischer. In the quarry at the top of mount Prospect it is 5 feet 4 inches in thickness	5=205
4.—Covered slope. On mount Prospect are shales, with some beds of laminated limestones about a foot in thickness	40=200
3.—At the top a drab to bluish limestone of irregular texture which weathers very unevenly. This layer is between $2\frac{1}{2}$ and 3 feet in thickness on mount Prospect. On Blue mount it forms the first marked ridge, and the slope below the outcrop of this ledge is covered to the top of the road cut	64=160
2.—Yellowish, bluish and blackish shales, with thin layers of argillaceous limestone (6 inches to 1 foot in thickness). The limestone in the cut near railroad level is somewhat bluish and contains fossils. The blackish shales near the top of the railroad cut at its southern end contain numerous fossils	64=96
1.—Covered slope to level of Big Blue river	32

The most important of these strata is No. 5, the Cottonwood Falls limestone, which has already been described in connection with the Kansas river section. This with the accompanying beds may be easily traced along the river bluffs nearly to Fort Riley, there being a good exposure at Seven Mile creek and at Ogden. The connection between the Manhattan section of Prosser and the Fort Riley section by Hay has been made by Prosser, the Cottonwood Falls limestone being 122 feet below the first flint beds according to barometric measurement.

The beds of the Fort Riley section are found succeeding those of the Manhattan section just west of Ogden. The section at Fort Riley as given by Hay* is as follows:

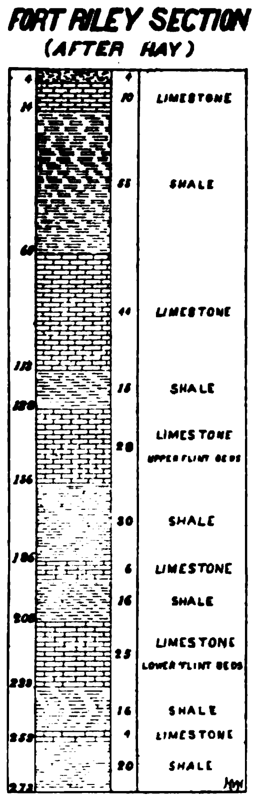
* Hay: Geology and Mineral Resources of Kansas, p. 8; Topeka, 1893.

Fort Riley Section. (After Hay.)

	Strata.	Fossils.	Thickness.
14.	Impure limestones, with some flints and numerous geodes	A univalve	10 feet.
13.	Light-colored shales, with lavender flag beds,	Athyris, pecten, pleurophorus,	50 to 60 ft.
12.	Buff limestones with shale partings, changing to shales with limestone ledges	Pecten, nautiloidea, athyris, meekella, hemipronites, martinia, fenestella, euomphalus, synocladia, schizodus	30 to 40 ft.
11.	The Fort Riley main ledge. A buff magnesian limestone in one thick ledge, with a thinner ledge resting on it. In places the ledges are continuous up into the layers of 12	Pecten, allorisma, martinia, athyris, retzia, hemipronites, synocladia, fenestella	6 feet.
10.	Shales, light colored and laminated	Producti, allorisma, chonetes,	15 "
9.	The upper flint beds. Limestones containing numerous flint nodules, and separated by definite layers of flints	Producti, chonetes, allorisma, martinia	25 to 30 ft.
8.	Shales, alternate colors, gray, greenish, maroon, brown	No fossils	30 feet.
7.	Limestone. The mid-shale bed, varying from a laminated, flaggy layer to a solid building stone four feet thick	Planorbis, and another univalve, allorisma, meekella, myalina, hemipronites, producti, etc	6 "
6.	Shales, alternate colors, as No. 8	No fossils	16 "
5.	The lower flint beds. The Wreford limestone. Flints as in No. 9. Parts of the beds are silicified in localities as if by infiltration	Crinoids, syntrilasma, athyris, retzia, pinna, meekella, producti, cup corals	25 "
4.	Shales. Bands of maroon and greenish gray, with a seam of coal on Humboldt creek	No fossils	16 "
3.	Limestone in cuboidal or rhomboidal blocks. In places oolitic. A seam of coal under it on Humboldt		4 "
2.	Shales, and buffy slate		10 "
1.	Slate, bluish and hard	Occasional discina	10 "

Here again the section is marked by a very prominent member, No. 11, which is the Fort Riley limestone. It gives character to the bluffs in the vicinity of Junction City, and is visible from the railroad on either the north or the south side of the river until it dips under the surface about three miles east of Chapman. The bed exposed on Indian Hill, just west of Chapman, is probably No. 14 of Hay's section at Junction City. Here the grading down of the wagon road has exposed a small flexure fault. A stratum of flinty limestone 2 feet thick shows a double fault, and a portion of the main ledge which has been displaced vertically about 7 feet is lodged nearly in the plane of the flint bed. There are also other indications of a slight flexing and faulting in this vicinity.

Above this, the highest bed in the Fort Riley section, there is the following section which completes the Permian series to the border


FORT RILEY SECTION
(AFTER HAY)
4
10 LIMESTONE
55 SHALE
44 LIMESTONE
15 SHALE
28 LIMESTONE
UPPER FLINT BEDS
30 SHALE
6 LIMESTONE
16 SHALE
25 LIMESTONE
LOWER FLINT BEDS
16 SHALE
4 LIMESTONE
20 SHALE

of the Dakota just west of Abilene, counting from the bottom upwards:

1. Variegated shales, olive and maroon	30 feet.
2. Thin-bedded limestone, exposed at Detroit	22 feet.
3. Light-colored shale	40 feet.
4. Limestone	5 feet.
5. Shale	25 feet.
6. Limestone exposed in north part of Abilene and in wagon road to Detroit, northwest of Abilene	8 feet.
7. Shale	40 feet.
8. Limestone, on hill at college north of Abilene	3 feet.

The Dakota does not rest upon the highest member of this series at this place, but crossing the creek west of Abilene it is found on lower ground. The sand springs west of town near four miles, and from which the water supply for Abilene is drawn, issue from under the Dakota as it rests on the Permian, probably No. 4 of the section just given. Fragments of the Dakota are found on the hill as far east as Fort Riley, but its eastern limit along this section is reached just after crossing the Superior branch of the Santa Fe railroad, in the western limits of Abilene.

CHAPTER VII.

A GEOLOGIC SECTION FROM COFFEYVILLE TO LAWRENCE.

BY ERASMUS HAWORTH.

The particular value to be derived from a description of this section depends upon a comparison of the conditions along this line with those of a parallel line nearly 50 miles to the east. As the outcropping of all the formations in this part of the state trend northeast and southwest this section should correspond closely with the Baxter Springs-Kansas City section in a general way with reference to everything excepting the lower systems which this one does not touch. Even here we have the various deep wells which throw much light on the underground conditions. The wells at Coffeyville, Cherryvale, Thayer, Chanute and Iola give us about as detailed information regarding the conditions below the surface as an areal examination can furnish for the surface, while the Lawrence well serves a similar purpose for a depth of a few hundred feet at the north end of the section. It is greatly to be regretted that records of the wells drilled years ago at Ottawa were not preserved. With them we would have had the section about as complete as one could desire, so far as deep borings could make it. It is reported that one or more wells have also been drilled at Garnett, but this Survey has been unable to obtain any definite information on the subject.

COFFEYVILLE.

At the south line of the state near Coffeyville the surface is beginning to assume the features characteristic of the great sandstone area farther west. Correlation of limestones in the Coffeyville well with those of the Cherryvale well is difficult and of little value. It seems that as the sandstone area is approached the limestone systems become irregular; some disappear, some change in thickness and general properties, and in many ways become altered so that it is difficult to recognize them. We will therefore have to take the underground section at Coffeyville for what it is worth, and recognize that it is located on the border of a great sandstone formation several hundred feet thick, and which corresponds in position, and possibly in time of formation, with limestone and shale formations to the north and east, and one about which this Survey does not at present possess sufficient data to make it possible to give much of a classification. The correlations indicated in plate VII should not be regarded of any particular value, yet they may be correct. Neither can the surface rocks be correlated with those to the north in an entirely satisfactory manner. It is quite evident that the rocks on top of the Cherryvale mounds dip to the south. If one will pass along the valley between the mounds and Drum creek on the west one can readily perceive this dipping. It is probable that the Mound Valley limestone or surface limestone at Cherryvale also dips to the south in a similar manner, and should be correlated with the Liberty limestone, and the lower one of the surface limestones at Coffeyville. In some way, and for some cause, the mounds and hills which are so characteristic of the vicinity of Cherryvale gradually diminish southward and practically disappear before the south line of the state is reached. For the details of the section at Coffeyville a reference to plate VII is all that is necessary.

CHERRYVALE.

At Cherryvale two different limestone systems are visible, the one capping the mounds and hills, and the other near the surface in the valley. They are separated by a shale bed which is 100 feet thick, as learned by measurement at the mounds south of town.

The upper limestone is thin, having been worn so by erosion, is well filled with fossils, dips to the west, thickens into 40 feet at Independence, and has been named the Independence limestone by Adams in chapter I. It also dips gently to the north, appearing again three miles south of Morehead at an elevation of 25 feet lower than the top of the Cherryvale mounds, giving a dip of 5 feet to the mile. Cherryvale is therefore situated on the summit of a gentle anticlinal ridge, the axis of which trends about north 70 degrees west and which dips rapidly to the west.

The lower limestone at Cherryvale is the first one shown in the drill record, and passes underground to the north and is seen no more in this section, excepting in the drill records. The conditions beneath the surface at Cherryvale have already been so fully described by Mr. Adams in chapter I that nothing need be added here.

The shales between these two limestones are unusually fragile and easily disintegrated. This accounts largely for the existence of so many mounds with steep sides around Cherryvale. In the process of weathering the shales yield rapidly, the superimposed limestones protect the surface, and the steep walls are the necessary results. The decay of the shales is so rapid that frequently vegetation cannot get a footing on the hillsides, and portions of the sides of different hills are therefore almost bare.

This shale bed corresponds to the thin bed at Uniontown lying between the middle and upper members of the Erie limestone system. The Independence rock near Morehead is quite prominent about three miles south of town. It is 10 or 12 feet thick here, and is quarried considerably by the Santa Fe road for ballast. It passes underground northward near Morehead and is seen no more.

THE THAYER SHALES.

Above the Independence limestone is a heavy shale bed nearly 200 feet thick, which may be named the Thayer shales. In places it carries much sandstone and good seams of coal. It constitutes the high ground on which Thayer is built, and the high plateau reaching westward towards Neodesha. The Thayer and Neodesha sandstone occur in it, as does also the Thayer coal, and the coal found in many places westward and southward towards Neodesha. This is

the lowest coal in the Upper Coal Measures occurring in sufficient quantity to be of any considerable commercial importance. The thickness of the seam varies, sometimes reaching nearly 30 inches. The Thayer mines are located in the upper portion of the Thayer shales, but some of the other banks nearer Neodesha seem to occupy lower positions.

The sandstones are quarried to a considerable extent, particularly around Neodesha. In places they produce fair building stone, as is shown by many different buildings in both Thayer and Neodesha, the materials for which came from the Thayer shales.

To the northeast the Thayer shales gradually grow thinner until they almost disappear in the vicinity of Boicourt and La Cygne. At Moran they are about 100 feet thick, at La Cygne they are not over 25. To the southwest they maintain their thickness, and possibly increase it. They constitute the main bulk of the high hills west and north of Neodesha from Benedict to the state line south. In places the hills are 200 feet above the valley, particularly Table Mound, the body of which is composed of the Thayer shales, at which place, according to Adams, they are 250 feet thick. These shale beds, as well as many others, illustrate how many of the deposits thicken to the southwest and thin to the northeast.

Northward the Thayer shales more nearly maintain their normal thickness. They constitute the shale beds in and around Chaunte. The coal mined north of Chanute is on about the same level geologically with the Thayer coal, but as the two are not connected directly we cannot well correlate them. Each of them is in the upper portion of the Thayer shales.

THE IOLA LIMESTONE.

The first limestone system of any special importance above the Thayer shales is the Iola limestone. It appears on the high hills southwest of Chanute, from which place its outcropping extends across the Verdigris river and along the eastern border of the high hills west of Neodesha and Independence to the state line. To the northeast its outcropping passes near Moran, Mapleton, Mound City, Boicourt, etc., as has already been described, and as is also marked on the accompanying state map. Where not reduced by

surface erosion the thickness of this system is about 40 feet along this line, but to the southwest, as Adams has shown in chapter I, its thickness is greatly increased.

In many respects this is a most remarkable limestone. Its lateral extent is great, reaching from the south line of the state to Kansas City, and probably much farther. The persistence of its characteristics throughout this whole distance is even more remarkable. It has few fossils, is unusually crystalline for a Coal Measure limestone, and is much freer from both vertical and horizontal fissures than any other limestone known below the Cottonwood Falls rock. This causes it to break into unusually large blocks. Some of the masses which are slowly working their way down the hillsides measure from 40 to 50 feet across. Then the general effect which the rock makes on one's mind by the ensemblence of all the properties cannot be easily forgotten, so that it is the most easily recognized limestone at sight occurring below the Cottonwood Falls system. The quarries at Iola have made the rock noted. The point of greatest interest in connection with the quarries is the almost total absence of any kind of fissures in the rock, which is here 39 feet thick. With proper mechanical appliances any kind of a block of any size or shape desired can be obtained, probably even to hundreds of feet in length. The rock is further noted for its high crystalline character. Strangely enough this Coal Measure limestone, in a country totally void of any approach to ordinary metamorphism, has from a half to two-thirds of its mass completely crystallized into calcite. This makes the rock capable of taking a high polish, hence the local name "marble."

THE CARLYLE LIMESTONE.

Above the Iola limestone is a shale bed 40 feet thick which has no special marks or characteristics. On top of these shales a limestone is first seen on the hills near Humboldt. It is only 5 or 6 feet thick here, but gradually thickens to the north until at Carlyle it is claimed by well-drillers to be 25 feet thick. It caps the little mound just south of Iola, and the hills to the northeast. It dips gradually toward the north and passes out of sight a short distance north of Carlyle. Kirk has mentioned it in chapter III as extending

from Iola up the river to beyond Neosho Falls. On account of its heavy development around Carlyle, it has been named the Carlyle limestone. Its northern extension is only partially known. It appears to reach a point opposite La Cygne and to cap the hills forming the first escarpment west of Cadmus and is the only one between the La Cygne hills and the Garnett limestone, but what becomes of it farther to the northeast has not been determined. Probably it disappears entirely, or approaches so close to the other limestones it is not recognizable. However, at points along the Kansas river a limestone is prominent which may be this one, as it occupies the same relative position.

THE LANE SHALES.

Above the Carlyle limestone we have a heavy and important shale bed which has already, in chapter III, been named the Lane shales. They are important because they have been instrumental in producing an interesting and characteristic topography, and because in places they carry so much sandstone. Along the line of our section it will be seen that the surface rises rapidly from Carlyle to Colony, which is practically located on the summit of the Lane shales, although the capping limestone does not appear for a few miles to the north. To the southwest in the vicinity of the Neosho river and beyond the shales are largely changed into sandstone. Yet the irregularity of the surface, the alternating hills and valleys show how irregularly this change has been produced. Had the sandstone areas been extensive laterally we should have had broad plateaus rather than alternating hills and valleys, as Kirk has described for that country. To the northeast the sandy or arenaceous character of the shales is not so marked. The great frequency of rugged, flat-topped hills characterize the country. The overlying limestone has been broken through along every stream, and bluffs with precipitous fronts have been produced. Isolated mounds are numerous also, standing as the last remnants of vast portions of the country almost entirely carried away. The Pottawatomie river flows almost parallel with the zone of country possessing the above-mentioned topography, passing the towns of Garnett, Greeley, Lane and Osawatomie. Farther to the northeast,

as was described in chapter II, the shales gradually become thinner, the Iola limestone gradually approaches the Garnett limestone above, and the whole aspect of the country is changed to correspond.

THE GARNETT LIMESTONE.

Above the Lane shales lie the two systems of the Garnett limestones. They are first observed at Welda, but from the surface contours there can be little doubt regarding their former existence as far south as Colony. Possibly they yet exist that far south near Colony to the east or west. They cover the surface all the way from Welda to Ottawa, Olathe and Eudora, and are found by drilling about 100 feet below the surface at Lawrence. They are plainly visible in section at many places along the Santa Fe line where it crosses the different tributaries of the Pottawatomie river on either side of Garnett. In such places there are two systems separated by from 10 to 12 feet of shale. The limestones themselves in most places are from 8 to 10 feet thick, but in extreme cases they thicken up to 30 feet or more. Such an instance was noted a few miles southeast of Greeley. Here by the roadside a bluff of solid limestone rises fully 30 feet, due to a local thickening of the upper system. From just beneath the limestone gushes a large spring of most excellent cold and pure water. The good farmer living here has placed a large watering trough below the spring and keeps other conveniences at hand, so that the passer-by, either man or beast, can slake his thirst. In this way the exact locality is known for miles around, so that anyone desiring to examine the place can easily locate it.

In places along the southeastern border of the Garnett limestone it seems that there is but one system, but this is probably due to the upper one having been eroded a little farther back than the lower. As the intervening shale bed is so thin no topographic mark could be noticed to show the exact limit of the upper system, and hence it would easily be overlooked. The intervening shale in places becomes exceedingly bituminous, so much so that it strongly resembles coal in general appearance, but this is a variable quality.

In addition to the good exposures of these rocks already mentioned we should add those near Princeton and at Ottawa. Just east

of Princeton the two systems are exposed along the creek and its small tributaries for miles. At Ottawa the lower system is in the bottom of the river, and the upper one forms the main part of the north bank. Here they are about 12 feet apart, being separated by a bed of light colored shale. Most excellent views of these limestones can also be had all the way down the Pottawatomie from Garnett to within four or five miles of Osawatomie. In the vicinity of Lane both systems become greatly thickened, but particularly the upper. In it are located the quarries of the Lane "marble," or limestone. The quarries are on the high hilltops about two and a half miles southwest of the village. The rock differs from the Iola "marble" principally in being darker in color. It possesses about as high a grade of crystallization as the latter, takes almost as fine a polish as the best of marble, and has a wide use for pedestals of tombstones, and other purposes.

From Ottawa to Lawrence we are largely in doubt regarding the exact position of the Garnett limestone, as it cannot be seen at any place throughout the whole distance. In a former article* it was assumed that the limestone at the south end of the dam at Lawrence was its equivalent. More recently, however, records of two wells have been obtained which correspond sufficiently well within themselves, and with known conditions around Lawrence to give considerable evidence of their correctness.† Admitting their evidence we must conclude that the Eudora limestone, as shown by Bennett in chapter VI and plate VI, is nearly 100 feet below the thin limestone at the dam, and therefore that the Garnett limestone is also; for we have satisfactory evidence that the two are the same. Plate VII represents this condition.

THE LAWRENCE SHALES.

First above the Garnett limestone lie the Lawrence shales. They are important as being in places the heaviest shales in the whole Coal Measures above the Cherokee shales, and therefore the heaviest in the upper Coal Measures. They contain here and there thin lime-

* Haworth: Kansas Univ. Quar., vol. 2, p. 121.

† This remark is made because the records as obtained were not guaranteed by anyone. They had been passed about through several hands, so that no one has been seen who knew how they were obtained. Ordinarily such records are useless.

stone beds, the most important one of which occurs about 100 feet below their summit. It has a thickness of 5 feet or more on the east side of Blue Mound, eight miles southeast of Lawrence, and almost an equal thickness across the Kansas river to the northeast. In each vicinity it occupies considerable prominence in the landscape, due partially to the sandstone beds immediately under it. But strangely it thins to an edge westward, northward and southward, so that no place has been found where it enters the high bluffs so prominent in the locality. It is therefore of but little importance stratigraphically, and should not be looked upon as dividing the Lawrence shales. The limestone at the south end of the dam at Lawrence is also somewhat difficult to place. Mr. MacFarland, who is conducting a brick-yard just above the city reports that he passed through 15 feet of limestone in a well located in the valley near the brick-yard. This would indicate that the river limestone is thickening westward. No trace of it, or anything that can at all be compared to it, can be found east, north, or south, so that we shall have to treat it at present as though it were an unimportant system, as one which never extended much beyond Lawrence eastward, recognizing the possibility of being in error. In this way we shall have to consider the Lawrence shales nearly 300 feet thick at Lawrence, which is 100 feet more than they had formerly been called.

The Lawrence shales are also noted for carrying coal, which in places is of considerable commercial importance, as has been shown by Hall in chapter V, and for containing so much sandstone that bears such strong evidence of having been deposited in shallow water. The sandstone is abundant about Lawrence. It occurs in a row of low hills southeast of the city, along the south bank of the Wakarusa, across the Kansas river to the northeast, and in many other places. Nowhere is it cemented into a good sandstone, nor are its layers well marked or continuous, so that it has no value as building stone. In the neighborhood of Hesper, where it is sometimes reached in well-digging, a layer of it is perfectly loose sand which caves so badly that the well has to be cribbed in digging. Almost everywhere the stone has ripple marks in great abundance, and not infrequently rain-drop impressions are seen.

OREAD LIMESTONE.

Above the Lawrence shales the Oread limestone appears in two separate systems, each of which in places is from 15 to 18 feet thick, but which near Lawrence is only from 10 to 15 feet thick. They have been so fully described by Mr. Bennett, in chapter VI, that nothing need be added here. The hills which they cap are first seen along this section to the west of Princeton, or possibly farther south. In their northeast-southwest trend they approach to within about three miles of Ottawa, and across the Santa Fe track between Norwood and Baldwin. Their southeastern outcropping passes around Baldwin to the east but swings back across the railroad westward near Vinland, from there to Lawrence and to the northeast near Tonganoxie, and crosses the Missouri river near Leavenworth, at which place they cap the high hills.

EVIDENCE OF DEEP WELLS.

We have now given a hurried description of the surface features along the Santa Fe railroad from Coffeyville to Lawrence. Plate VII also gives considerable information regarding the underground conditions. At Cherryvale and Chanute wells start from the upper Coal Measures and pass into the Mississippian. They thus give us the thickness of the different formations in the lower Coal Measures over fifty miles back from the outcroppings of the Mississippian series. It will be seen that the Cherokee shales have maintained their thickness remarkably well. At Coffeyville they are not less than 400 feet, but the well did not pass through them. At Cherryvale they are nearly 425 feet, and at Chanute they are 410 feet, while to the west, at Neodesha, they are fully 425 feet, and at Fredonia 350 feet. It will also be seen that probably the upper surface of the Mississippian is wavy, or has general irregularities not due entirely to pre Coal Measure erosion, although having but three points located leaves one liable to err. The general features, therefore, of the Mississippian and the Cherokee shales are remarkably similar to those shown along the Baxter Springs-Kansas City section, plate II. The conditions above the Cherokee shales are not quite so pronounced, but on the whole correspond with the surface features to the east very well. Here we have the additional evidence of the

wells at Thayer, Humboldt, and Iola. At no place from Coffeyville to Iola is there a space greater than 18 miles without a well record, which places matters safely beyond the realms of conjecture. It will be noticed that all the wells show that first above the Cherokee shales is an area occupied principally by limestone, the Oswego and the Pawnee, with thin shale beds between. The details to the extent of exact feet and inches are difficult to obtain from deep wells, but there is a general agreement among all of them. Next above this limestone area is a heavy shale and sandstone area, the Pleasanton shales, at the top of which we have placed the division of the Coal Measures, dividing them into the Upper and Lower, with the Lower division along the line of this section, 700 feet thick at Coffeyville, 700 feet at Cherryvale, 850 feet at Thayer, and 800 feet at Chanute, with no indication of its thinning toward the north. Above the Pleasanton shales we have the Erie limestone system, which is plainly marked at Iola, Humboldt, and Chanute. Above these limestones we have another shale deposit about 100 feet thick, above which lies the Iola limestone. In a general way, therefore, the underground conditions here, as shown by the well records, have a remarkable agreement with the surface conditions fifty miles to the east.

CHAPTER VIII.

A GEOLOGIC SECTION FROM ATCHISON TO BARNES, ALONG THE CENTRAL BRANCH OF THE MISSOURI PACIFIC RAILWAY.

BY E. B. KNERR.

Passing from the top of the bluffs about Atchison to the level of the Missouri river the following outcroppings in the bluffs may be observed:

1.—50 to 60 feet of drift.

2.—Below this there is evidence of shale in some places.

3.—A weathered limestone in places about 2 feet thick.

4.—2 feet of clay.

5.—2 feet of limestone.

6.—2 feet of black slippery shale.

7.—2 feet of limestone rich in *Fusillina*, darker than the following yet lighter than the most of the Atchison limestones.

8.—2 more feet of limestone, very light in color and much resembling Cottonwood Falls rock, but not porous.

9.—5 feet of shale.

10.—6 feet of limestone very good for building, and mostly used for such purpose.

11.—2 feet of shale.

12.—4 to 8 inches of coal.

13.—4 to 10 feet of shale.

14.—6 feet of sandstone which runs into shale in places and is common in all the bluffs.

15.—20 to 25 feet shale, used extensively for the manufacture of vitrified brick.

16.—2 feet of a hard compact limestone broken at regular in-

tervals into large monoliths, very similar to No. 22 in appearance.

17.—5 feet of shale.

18.—6 feet limestone.

19.—4 to 6 feet of shale.

20.—21 feet of limestone, more or less flinty, of little or no value for building purposes, used extensively for railroad ballast (the upper of the Oread limestones).

21.—3 to 4 feet of a laminated shale containing more or less pyrite nodules.

22.—21 inches of a hard firm limestone which breaks off in immense blocks, and which is conspicuous in all the bluffs.

23.—9 feet of shale.

24.—10 feet of limestone.

25.—25 feet of shale.

26.—16 to 18 inches of coal, which is worked at the Donald and Ada mines two miles south of Atchison.

27.—30 feet of shale.

From this it will be seen that the bluffs about Atchison rise to a height of over 200 feet above the Missouri river.

Westward from Atchison the drift is quite heavy and for the most part hides the limestones so effectually that their outcroppings are seldom visible even in the beds of streams. These limestones would be the thin layers visible in the crowns of the bluffs about Atchison. Above the highest rocks discoverable about Atchison there is evidence of quite a heavy deposit of shale. This will help to account for the peculiar rolling and hilly character of the country directly west of that place.

About eight miles to the southwest, near Hawthorne, the 21-foot limestone (the Oread) is again visible. In the bed of Stranger creek at Monrovia about 18 inches of limestone in thin layers of 6 to 8 inches at most is quarried.

About two miles north of Muscotah and twenty-two miles west of Atchison an interesting series of limestones occur:

1.—At the top is limestone 21 inches thick.

2.—37 feet of shale.

3.—30 inches of hard limestone.

4.—8 feet of shale.

5.—18 inches of limestone.

6.—3 feet of shale.

7.—10 inches of limestone.

8.—12 feet of shale.

9.—18 inches of arenaceous limestone.

10.—A shale reached by shafting; bears a small deposit of coal.

The limestone at the top of this series and the 30-inch deposit (3) are quarried for building purposes.

From Muscotah to Centralia is a long stretch of rolling prairie which presents no outcroppings whatever in the neighborhood of the railroad. But to the north at Granada a limestone is quarried which is without doubt a representative of a certain limestone exposed at Frankfort 30 miles to the west, underlying the Cottonwood Falls rock. However, no Cottonwood Falls rock proper is found north of the Central Branch in that vicinity. But directly south about twelve miles, in the vicinity of Circleville, the Cottonwood Falls rock occurs in abundance 6 feet thick, and may be traced to the northwest as far as Frankfort, where the line of outcrop curves to the north and disappears under the drift about five miles north of Beattie in Marshall county.

About five miles northeast of Centralia, and about the same distance south of Seneca, the following outcrops were observed:

1.—The drift at the top.

2.—Next below lies 30 inches of limestone.

3.—25 feet of shale.

4.—6 feet of limestone.

5.—18 feet of shale.

6.—An 18-inch layer of limestone.

7.—At the bottom lies a shale bearing a 4-inch stratum of coal.

The 30-inch deposit of limestone is extensively quarried for building purposes. These same rocks and the coal-bearing shale occur about 18 miles to the southwest near Neuchatel on Coal creek. Here they are shown to underlie the Cottonwood Falls rocks, as these latter may be found about eight miles to the east and about 50 to 100 feet above them. No good exposure showing their exact

amount of separation could be found, but the distance is approximately 60 feet.

From Centralia to Frankfort is a rolling prairie devoid of all rock other than the boulders of the drift.

South of Frankfort the bluffs rise to a height of 160 feet above the railroad and have the Cottonwood Falls limestone on their summits, about 4 feet thick. Beneath these to the base of the bluffs is a succession of shales 15 to 30 feet thick alternating with ledges of limestone 1 to 5 feet thick. The ledges of limestone terrace the bluffs, about 6 terraces being especially prominent.

A little to the south of Bigelow the Permian first becomes conspicuous in the bluffs called Twin Mounds. Here the Cottonwood Falls rock is about 30 feet above the railroad and is 6 feet thick.

The following section is observed reaching from the top of the mound to this Cottonwood Falls rock:

1.—10 feet of limestone with flint nodules very abundant in the upper portion.

2.—50 feet of buff shales and thin limestones.

3.—30 inches of porous limestone with 8 to 10 inches of a prismatic blue flint overlying it.

4.—About 30 feet of shales and thin limestones.

5.—30 inches of a hard prismatic limestone.

6.—2 feet and 10 inches of a compact limestone.

7.—A 3-foot bed of calcareous shales very full of fossils.

The upper strata (1) containing the flint are very characteristic and persistent. They were traced north along the Blue river to the Nebraska line, and west to Washington county. They occasion the flat-topped bluffs so conspicuous on either side of the Blue river from Bigelow to Waterville. The flint nodules in the upper stratum are quite like agate in concentric structure. The limestone in which they are imbedded is quite soft and weathers easily leaving the nodules exposed and protruding.

At Waterville two more deposits of the Permian become conspicuous over the flinty nodular limestone. They are each about 60 feet thick and are made up of buff shales and thin limestones of a similar color. They are separated by about 2 feet of buff limestone so persistent and uniform as to cause a terrace in the bluffs.

This intermediate limestone and a similar ledge over the next series of shales above form the crowns of the flat-topped bluffs west of Waterville, while the flinty nodular limestone crowns the bluffs about Blue Rapids.

Five miles beyond the county line in Washington county, near Chepstow, the Permian rises still 40 feet higher by a third series of shales and thin limestones. Over this the Dakota sandstones rise to an elevation of 98 feet. Thus we estimate the Permian over Cottonwood Falls limestone to measure about 250 feet.

The gypsum deposits about two miles west of Blue Rapids and a mile or two northwest of Waterville are located in the shales between the Cottonwood Falls limestone and the 30-inch Permian limestone which has the prismatic flint over it. The gypsum bed near Blue Rapids is about 9 feet thick and very pure.

The principal limestones in the region discussed are the 21-foot stratum at Atchison; the 10-foot layer beneath this and the 6-foot ledge above; the Muscotah series; the series between Centralia and Seneca, also observed at Neuchatel; the Cottonwood Falls series; the Permian ledge with the prismatic bed of flint over it, and Permian ledge with flint nodules. Of all these, the most important commercially and the most interesting geologically is the great Cottonwood Falls system.

CHAPTER IX.

RESUME OF THE STRATIGRAPHY AND CORRELATIONS OF THE CARBONIFEROUS FORMATIONS.

BY ERASMUS HAWORTH.

The eight preceding chapters have been chiefly devoted to detailed descriptions of the stratigraphy of as many different sections reaching wholly or partially across the Carboniferous formations of the state. This chapter will be devoted to a general review of the stratigraphy of the whole area, an attempt to correlate the different

systems, and point out any general principles which may have been omitted or only partially discussed in the preceding chapters. It may at times be necessary to repeat statements already made in order to place the matter properly before the reader.

One of the first conceptions to be gained regarding the stratigraphy of the Carboniferous is that in general nearly all the formations above the Mississippian both dip and thicken to the west, particularly in the Coal Measures, and that occasionally a wedge shaped formation which may be quite heavy under ground at one place fails to reach the surface to the east on account of its thinning out in that direction until it entirely disappears. The second point of general importance is that while the Carboniferous consists of limestones, sandstones, and shales, the limestones are by far the most regular and persistent laterally, and therefore are of the most importance stratigraphically, although they never nearly equal the others in thickness. There are great shale beds, it is true, which are remarkably persistent and tolerably regular. If we look upon them as the principal formations with occasionally included sandstones, into which they may grade and again change back into shales, we can use them very well. In this way we would consider but two formations, the limestones and the shales. Our drawings for plates I to VIII inclusive were made in this way, the limestones being represented by the ordinary conventional masonry, while the shale beds with their included sandstone are left blank. It is believed not only that this is the best mode of representation to impart to the casual observer a fair idea of the stratigraphy of the Carboniferous, but that the student who, with report in hand, may pass over the ground to correct or verify the conclusions here reached will also find it to his advantage actually to think of them in this way.

OUTLINES OF STRATIGRAPHY.

Beginning at the base of the Carboniferous we will now mention in ascending order each formation of any considerable thickness up to the Dakota Cretaceous, and add such remarks of a general character as may be deemed advisable in order to give a clear and connected description of the location and extent of each of them. The detailed descriptions already given for different localities will be

referred to quite often, and the different drawings will be freely used. Plate XXII is a generalized section of the Carboniferous. The total thickness here given above the Mississippian is 800 feet for the Lower Coal Measures, 1,950 feet for the Upper Coal Measures, and 795 feet for the Permian, the thickness of the Mississippian being indeterminable within the state excepting by drilling. The maximum thickness of the different formations was never used in making these estimates; neither was the minimum. Probably at no one place would the drill prove the distance to the Mississippian to quite equal these figures, but there certainly could not be much of a decrease in the thickest portions.

A.– THE MISSISSIPPIAN.

The Mississippian area within the state is so small, one must necessarily go beyond the limits of Kansas to study it. Yet the unusually rich deposits of lead and zinc ores within it have given to the thirty square miles in the southeastern part of the state a reputation for productiveness unequalled perhaps by any like area in the world. Earlier geologists have placed these rocks in the Keokuk group, which constitutes one member of the "Augusta" of Keyes.* They are composed of limestones and cherts irregularly interbedded, with shales appearing in some localities. The chert constitutes nearly all of the rocks in certain places, particularly in the mining districts where it carries the greater portion of both the lead and zinc ores. In other places the chert becomes less permanent and the limestone increases in relative proportion. Along the north bank of Short creek at Galena the limestone is tolerably common in the bluffs and hillsides, but to the south it seems to have been eroded away or replaced by chert. Both the limestones and cherts are well filled with invertebrate fossils.

The upper surface of the Mississippian was badly eroded before Coal Measure time, at least near the eastern borders of the Coal Measures, as expressed in chapter I. Westward and northward the formation extends as far as deep drilling has been done, so that we have good evidence that it underlies all of eastern Kansas. Its sur-

* Iowa Geol. Surv., vol. 1, p. 59; Des Moines, 1892.

face inclines rapidly to the west and northwest, but it cannot be determined whether or not the surface erosion extends very far in this direction, as the information given by the drill would have no positive bearing on the subject. By recalling the depths at which the Mississippian was reached along the lines of the various sections already described, we can locate this surface quite well. It seems to decline westward more rapidly than in any other direction, as will be seen from the following summaries. At Galena it occupies the hilltops a thousand feet above sea level with the lowest valleys about 850 feet. At Oswego it has been reached by at least two wells 400 feet above sea level, which is a decline of fully 475 feet from the valleys at Galena, twenty-five miles away, or of about 600 feet from the hilltops, or something over 20 feet to the mile. Wells at Stover and Mound Valley did not reach the Mississippian, but at Cherryvale fifty miles away it was reached 1,008 feet below the surface, which places it 180 feet below sea level. As this well was made with a diamond drill and an excellent core preserved* there can be no reasonable doubt about the correctness of these figures. This gives a westward inclination of more than 20 feet to the mile. At present we have no definite data regarding the depth from the surface to the Mississippian west of Cherryvale. A well three miles west of Independence reached 1,100 feet without striking it, one at Niotaze 1,158 feet, and one at Wichita 1,950 feet, so we can only say it lies below these several depths at the respective places. To the northwest it was reached at Neodesha 135 feet below sea level, at Fredonia 310 feet, at Fall River 430 feet below sea level, giving about a 17-foot decline to the northwest. At Osage Mission, thirty-nine miles from Galena, a well 700 feet deep failed to reach it. At Chanute, fifty-eight miles away, it was reched 36 feet below sea level, and at a few other points in that vicinity at similar depths. The decline from Galena to Chanute straight northwest is consequently nearly 17 feet to the mile, considerably less than in a more westerly direction. Northward along the east line of the state it was reached at Girard 493 feet above sea level, at Fort Scott 385 feet above sea

*This core has recently been lodged in the museum of the University of Kansas in a well preserved form, where it can be examined by any geologist wishing to do so.

level, at Pleasanton 206 feet above sea level, at Paola* 182 feet below sea level, at Kansas City at sea level, and at Leavenworth over 300 feet below sea level. A well at Topeka 1,638 feet deep, or about 775 feet below sea level, failed to reach it, and one at McFarland 2,006 feet deep, or about 1,000 feet below sea level, failed to reach it. The inclination from Galena to Kansas City is, therefore, only about 6.5 feet to the mile. But as the southeastern boundary of the Coal Measures is a line running northeast and southwest the latter point should be reckoned, not from Galena, but from the nearest point of surface exposure of the Mississippian. According to the geological map of Missouri published by Winslow† the Mississippian occupies the surface at Sweet Springs and a few miles to the west, bringing it to within fifty miles or less of Kansas City. Reckoning in this way we have a decline of the floor from near Sweet Springs to Kansas City of about 15 feet to the mile, to Topeka at least 14 feet, how much more we cannot say, and to McFarland of 13 feet to the mile, with probably considerably more, which is less than the decline along the southern line of the state. From the above data we can calculate the decline in any direction. From Kansas City to the southwest we find almost a level in the floor towards Chanute and Cherryvale, but a decline of about 3 feet to the mile towards Fall river.

From these and other similar data we may conclude that the Mississippian formation underlies all, or nearly all, of the Coal Measures in Kansas, and that its upper surface is strongly inclined westward, equalling 20 feet to the mile along the south line of the state, and at least 10 feet to the mile for the whole distance to Wichita, and probably more, while to the north as far as Kansas City the inclination averages only about 6.5 feet to the mile, with an intermediate value in intermediate directions. According to Winslow,‡ in a direction northwest from Sedalia the Mississippian floor declines about 1,600 feet in 150 miles, or a little more than 10 feet to the mile, but he gives no data regarding the inclination in other directions.

* A little doubt has been expressed regarding the correctness of this well record. The record used is preserved in the city public library at Paola. The criticism is to the effect that the Mississippian comes about 200 feet nearer the surface, which would correspond better with its depth at Pleasanton and Kansas City.

† Preliminary Report on Coal, 1891, and succeeding volumes.

‡ *Ib.*, p. 24.

B.—THE COAL MEASURES.

THE CHEROKEE SHALES.*

First above the Mississipian, or at the base of the Coal Measures, lie the Cherokee shales with an average thickness of about 450 feet, which, with their included sandstones, constitute the most remarkable formation in some respects in the whole Coal Measures. They have great lateral extent, as is shown from many drillings; how great is not determined. At Cherryvale they are nearly 425 feet thick; at Neodesha fully 425 feet; at Chanute 410 feet, and the deep wells at Humboldt and Iola did not pass entirely through them; at La Harpe they are 345 feet; at Fredonia they seem to be only about 350 feet, but they thicken again to 375 feet at Fall River. To the north they reach to Leavenworth, with the following thicknesses at the various places, as shown on plate II: Girard 446 feet, Fort Scott 410 feet, Pleasanton 440, Paola 750,† Kansas City 420, Topeka at least 700, and Leavenworth 540. With such thicknesses as these at the different places named, we may well conclude they reach much farther to the west. There are also many reasons for believing that the same shale beds reach entirely across the state of Missouri and into Iowa. Broadhead‡ mentions a few deep borings, particularly one in Ray county, which shows them to be about 400 feet thick at that place, and in his general section of the Missouri Coal Measures he gives from 350 to 450 feet of shales and sandstones at the base. Other wells recently drilled in northern Missouri bear similar evidence. From the accounts of the Iowa Coal Measures given in the different reports of that state and from the writer's knowledge of portions of the state, it is reasonably certain that nearly the whole of the Iowa Coal Measures have a heavy shale bed at their base, the Des Moines formation of Keyes,§ which connects directly with the similar one in Missouri and that in turn with the Cherokee shales in Kansas. Southward into the Indian Territory the same shale bed extends for many miles, and probably it connects with the heavy shale beds at the base of the Coal Measures in

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* Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 105, Jan., 1894.

† See first foot-note, p. 149.

‡ Missouri Geol. Surv. Rep., 1872, part 2, p. 83.

§ Iowa Geol. Surv. Rep., vol. 1, page 126; Des Moines, 1894.

Arkansas and Texas, making one continuous formation many hundred miles in extent. This correlation has not been definitely determined, but there can be little doubt of its correctness.

In character the Cherokee shales vary greatly both vertically and laterally. Portions of them are bituminous, portions are argillaceous, and arenaceous. In color they are as variable as in composition. Some are almost a jet black, others a light gray, and others representing the various colors usually characteristic of Coal Measure shales. They are exceedingly rich in coal, producing at the present time more than two-thirds of the whole amount mined within the state, supporting all the mines in the vicinity of Weir City, Pittsburg, Cherokee, and to the northeast to Arcadia, as well as those about Fort Scott and Leavenworth. The well records to the west show frequent veins of coal. At Cherryvale a 27-inch vein was passed about 15 feet above the base, and several lesser ones above. At Topeka 11 veins were passed, while every well record examined shows three or more.

Here and there throughout the Cherokee shales greater or lesser beds of limestone occur, usually from 6 to 15 inches in thickness, of very limited lateral extent, but occasionally 4 or more feet, although none of them seem to have sufficient lateral extent to be of importance stratigraphically. They generally contain many invertebrate fossils from the list of which the following are taken:* *Fusulina cylindrica* in extreme upper portion, *Ptilodyctia triangulata*, *Rhombopora lepidodendroides*, *Athyris lamellosa*, *Athyris subtilita* (found in almost every limestone in the Coal Measures), *Chonetes mesoloba*. *Discina nitida*, *Productus longispinus*, *Productus costatus*, *Spirifera camerata*, *Spirifera plano-convexus*, *Spirifera lineata*, *Nucula ventricosa*, *Schizodus* ——— (very large), *Bellerophon carbonaria*, *Macrocheilus primigenius*, *Nautilus plano-voluis* (?).

THE OSWEGO LIMESTONE.†

Above the Cherokee shales are two limestone systems separated by from 4 to 7 feet of an unusually black shale. Each is from 5 to 15 feet thick, and they are wonderfully persistent laterally for lime-

*Copied from catalogue of Kansas Coal Measure fossils prepared by Rev. John Bennett, Fort Scott, and constituting chapter XV of this volume.
†Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 105, Jan., 1894.

stone so thin. The Cherryvale, Neodesha, Fredonia and Fall River well records show they extend that far west. They outcrop on the surface in a sinuous line passing from the south side of the state to the northeast by way of Oswego, Girard, and Fort Scott, near which point they cross into Missouri, and they are found at or near the surface over the zone from 5 to 15 miles wide lying northwestward from their line of outcropping. Some of the different well records to the north show them, and quite likely they were passed in the borings at Kansas City and Topeka, although one cannot well decide regarding so thin limestones without more intervening wells. The lower limestone is the "cement rock" quarried and manufactured so extensively into hydraulic cement at Fort Scott. These two limestone systems are so close together that they may be classed as one; yet the black shale lying between them is widespread and so bituminous that it must have been formed in very shallow water and close to a dry land area.

Both of the limestones and the associated black shales are well filled with fossils, from the list of which the following are representatives. The corals and crinoids are particularly abundant and large: *Fusulina ventricosa* (?), *Campophyllum torquium*, *Syringopora multatenuata*, *Zeacrinus mucrospinus*, *Chaetetes milleporaceus* (very plentiful), *Ptilodictia triangulata* (rare), *Rhombopora lepidodendroides*, *Chonetes mesoloba*, *Productus costatus*, *Productus nebrascencis*, *Productus punctatus*, *Retzia mormoni*, *Rhynchonella uta*, *Spirifera lineata*, *Allorisma subcuniata*, *Aviculopecten* ——— (first seen in upper limestone), *Nuculana bellistriata*, *Orthis carbonaria*, *Bellerophon montfortanus*, *Naticopsis ventricosa*, *Pleurotomaria sphaerulata*, *Gonetites* ———, *Nautilus ferratus*, *Orthocerus rushensis*, *Phillipsia major*.

Above the Oswego limestone lies a bed of shales of variable thickness. In places it is over 40 feet, but the borings at Mound Valley and Cherryvale and all those made north of Thayer as well as those north of Fort Scott show that it almost entirely disappears in those directions. North of Fort Scott it carries considerable coal which supports local mines.

THE PAWNEE LIMESTONE.*

Above the shale bed last mentioned a limestone occurs in the southern part of the state which also thins towards the north. It was recognized by Swallow, and has been mentioned by almost every geologist writing on that locality since. It is particularly well developed in the vicinity of Fort Scott and to the southwest for a number of miles, as has already been given by Bennett in chapter IV. It may be noted as having the least lateral extent in proportion to its maximum thickness of any limestone system known in the whole Carboniferous area. Yet possibly after all, could we have authentic records of wells sufficiently close together to the west and north, we might be able to prove its existence for a greater distance than is now known. As the shales between it and the Oswego limestones thin out to the west and north the Pawnee limestone and the Oswego limestone are brought close together, so that in a way they may be looked upon as constituting one great limestone system. Various well records to the northwest show this. We have, therefore, above the Cherokee shales and below the next great shale bed a series of limestones the existence of which is proved by almost every well record studied in the state, so that one or all they are of very great lateral extent.

The Oswego limestone and the Pawnee limestone are rarely if ever horizontal, and the dip is quite irregular. As pointed out in chapter II, they abound in small and low anticlinals and synclinals. These irregularities are as great as almost any others noticed in the whole area.

The Pawnee limestone affords the following fossils in considerable abundance, with many others not given: *Cyanthaxonia distorta*, *Lophophyllum proliferum*, *Fistulapora nodulifera*, *Productus longispinus*, *Spirifera lineata*, *Spiriferina kentuckiensis*, *Pleurotomaria sphaerulata*.

THE PLEASANTON SHALES.†

Above the Pawnee limestone are the Pleasanton shales, which in places approach 250 feet in thickness. Their greatest thickness is towards the southwest. To the north from Pleasanton they rapidly

*Swallow: Geology of Kansas, 1866, p. 24.
†Haworth: Kansas Univ. Quar., vol. 3, p. 274; Lawrence, April, 1895.

grow thinner, so that at Fontana and Paola they are relatively unimportant, but they thicken again until at Kansas City they are 180 feet thick. Southwestward from Pleasanton they maintain their thickness quite well and constitute a considerable portion of the high divide between the Neosho and Verdigris rivers. As is so common with all the Carboniferous shales, they often grade into sandstone, which in turn passes back to shales, so that wherever they are examined one is liable to find considerable arenaceous properties. At their summit at Boicourt a heavy bed of sandstone from 10 to 12 feet thick has furnished large quantities of stone for bridge building and other purposes. In places they also carry extensive beds of flagging stone, for detailed information of which the reader is referred to the preceding chapters, particularly chapter IV.

The Pleasanton shales also carry large quantities of coal. In the vicinity of Pleasanton and Boicourt coal mining has been conducted for nearly 40 years, earlier by the strip pit method, but more recently by shafting. At least two distinct veins of coal occur nearly a hundred feet apart, and possibly more, so that they are quite noted in this respect. Here and there also considerable calcareous material is met with. In the section along the Marmaton one limestone mass aggregating 8 feet in thickness was described by Bennett, yet its lateral extent was not sufficient to warrant a separation of the shale bed on account of it. Other lesser limestone masses have been found, all of which carried an abundance of fossils, of which the following may be named: *Cyanthaxonia distorta; Athyris trinuclia*, very rare; *Chonetes mesoloba*, last seen here; *Discina nitida*, becoming rare; *Rhynchonella uta.*

According to Mr. Bennett there is the greatest change in the fauna at the top of the Pleasanton shales noted anywhere in the Coal Measures. For this and other reasons the top of this shale bed has been chosen for the uppermost limit of the Lower Coal Measures.

THE ERIE LIMESTONE.*

At the close of the formation of the Pleasanton shales a limestone forming period was ushered in. Limestone almost to the extent of 100 feet in thickness was formed in some parts of the state, not

* Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 188; Lawrence, Jan., 1894.

in one continuous mass, however, but separated by thin and relatively unimportant shale beds. As shown on the surface this process was carried to the highest degree of perfection in the country to the west of Fort Scott, and is well illustrated in plate IV. Here we have three distinct systems one above the other which are so close together that they properly should be regarded as one great system. To the south, however, they soon separate considerably, so that the intervening shale beds assume considerable thickness. The individual limestone systems also decrease somewhat in thickness, and therefore have been a less important factor in producing the topography of the country. The lower one seems to pass a little above Osage Mission, from there to the east of Parsons a mile or two, and by the way of Altamont to beyond the south line of the state, leaving the great bed of Pleasanton shales between Altamont and Oswego. Throughout this distance the outcropping of the limestone is not very strongly marked by surface features. The middle of the three limestones likewise passes to the southwest with its eastern margin gradually growing farther from the Altamont limestone, so that it passes near Mound Valley southward to beyond the state line. In this case, however, there is a bold escarpment which marks its eastern limit from the state line northward fifteen or twenty miles, beyond which it gradually merges into a similar escarpment produced by the Erie limestone systems combined. At Mound Valley the vertical distance between the middle and the lower of the three limestones is approximately 125 feet, as has been explained by Adams in chapter I. The uppermost of the three limestones follows a course similar to that of the other two, excepting its eastern boundaries bear to the west more decidedly still and pass near Erie, Galesburg, Cherryvale, and Liberty. Throughout portions of this distance a strongly marked topography results from the combination of conditions produced by the limestone and the underlying shale bed. For many miles there is a row of bluffs or isolated mounds similar to those in Mound Valley, only more pronounced.

From the vicinity of Uniontown northward the Erie limestone systems remain tolerably close together, passing Mound City, Pleasanton, Boicourt, La Cygne, and Fontana, and reaching to the north-

east across the state line. Throughout the whole distance the topographic features are similar to those in the vicinity of Mound Valley and Cherryvale, but here they are produced by the Erie limestones serving as a protection above the Pleasanton shales which have their maximum thickness in this vicinity. These limestones as a whole are very interesting in many ways. Their separation to the southward producing the radiated structure is different from that usually found in the state, the uppermost layer thickening so rapidly to the westward from Cherryvale, reaching a thickness of 40 feet at Independence, and the remarkably large masses of flint which they carry, particularly in the vicinity of Uniontown, are some of their prominent characteristics. Northward they extend to the bluffs along the Missouri river. Broadhead* has named the lowermost member the Bethany Falls limestone, number 78 of his section. According to his report it reaches from the north line of Missouri to Kansas City. In a section made by Professor Tilton† a heavy mass of limestone is met with between Bevington and Winterset which has been traced southward to the Missouri line, where the lower portions of it may be correlated with the Bethany Falls limestone.‡ To the northwest from the outcropping of the Erie system every well record examined shows large quantities of limestone to exist. It seems that they represent a period noted all over the Carboniferous of Kansas for great limestone productions. The shale partitions between them vary in thickness, sometimes aggregating several hundred feet, as from Altamont to Cherryvale, at other times dwindling to so thin beds that in some of the well records, particularly the one from Fall River, the shales are scarcely represented, although they were actually present. In other places the shales first above the Erie limestone, the Lane shales, grow thin so that the Erie limestones seem almost to coalesce with the great Iola limestone beds, which intensifies the limestone forming action at this period. Every well record studied for the whole state shows

* Report Missouri Geol. Surv., 1872, part 2, p. 77.

† Iowa Geol. Surv. Rep., vol. 3, p. 137; Des Moines, 1895.

‡ Keyes, Am. Jour. Sci., vol. 50, p. 243; New Haven, 1895. Doctor Keyes suggests that inasmuch as this correlation has been perfected, the term Bethany Falls limestone should be applied to the whole group. It is quite evident that Broadhead did not intend his name Bethany Falls to be used in so extensive a sense, and as the term Erie limestone was proposed nearly two years before the suggestion made by Doctor Keyes, priority would not allow the use of the term as he suggests.

that aggregated or separated they occur in increasing thickness westward, increasing principally at the expense of the intervening shale beds.

The Erie limestones abound in fossils, from the list of which the following species are selected as representatives: *Fusulina cylindrica, Axophyllum rudis, Campophyllum torquium, Archiocidaris mucronatus, Archiocidaris triserrata, Erisocrinus typus, Eupachycrinus tuberculatus, Scaphocrinus hemisphericus, Zeacrinus acanthophorus, Serpula incita, Spirorbis carbonaria, Fennestella* ———, *Polypora submarginata, Synocladia biserialis, Chonetes granulifera, Chonetes smithi, Chonetes millepunctatus, Orthis precosi, Orthis robusta, Orbiculoida* ———, *Productus americana, Productus pertenuis, Productus symmetricus, Syntrialasma hemiplicata, Terebratula bovidens, Allorisma granosa, Allorisma reflexa, Allorisma subcuneata, Aviculopecten carboniferus, Aviculopecten interliniatus, Aviculopecten providencensis, Aviculopecten americana, Chaenomya leavenworthensis, Conocardium obliquan* (very rare), *Edmondia aspinwallensis, Edmondia ovata, Edmondia reflexa, Macrodon carbonarius, Monopteria gibbossa, Myalina subquadrata, Myalina swallowi, Nucula parva, Pinna paracuta, Pleurophorus oblongus, Schizodus wheeleri, Solenopsis solenoides, Bellerophon crassus, Loxonema rugosa, Naticopsis gigantia, Platyceras nebrascenses, Pleurotomaria turbiniformia, Pcupa vitusta, Conularia crestula, Goneatites lyoni, Nautilus occidentalis, Nautilus ponderosus,* etc.

THE THAYER SHALES.*

Above the Erie limestone in the southern part of the state heavy shale beds occur, which in Neosho, Wilson and Montgomery counties reach a maximum thickness of over 200 feet, but which grow thinner northward until they became less than 30 feet in thickness. They are prominent from Chanute to the southwest, and constitute the main masses of the bluffs along the Verdigris and Fall rivers from Benedict and Fredonia southward to beyond Independence. The famous Table Mound north of Independence is composed almost entirely of them, on the western side of which a section of 200 feet or more is shown. They have been passed through by every prospecting well

*These shales were called the Chanute shales, Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 109, Lawrence, January, 1894; but were changed to Thayer shales, Kansas Univ. Quar., vol. 3, p. 276, Lawrence, April, 1895.

in this part of the state west of their outcropping, so that we know they extend many miles westward under the superimposed strata. They frequently grade into sandstone, furnishing many workable quarries of that rock in various places, particularly in the vicinity of Thayer, Neodesha, and Independence. Ripple marks and other indications of shore deposits are frequently found in them and the arenaceous shales associated with them. These shales also carry two or more seams of coal, which are mined locally to a considerable extent in the vicinity of Thayer, from which the surrounding country is largely supplied.

THE IOLA LIMESTONE.*

At the close of the period in which the Thayer shales were produced a great limestone-forming period was ushered in, producing the most extensive limestone system to be found anywhere within the Carboniferous of the state—the Iola limestone. To the southwest, in the vicinity of Elk City, it is reported from a well to be 100 feet thick. Northeast of this it diminishes in thickness until, at Iola, it is only 40 feet. Still farther northeast it diminishes more, so that in places it is not more than 20 feet thick; but in the vicinity of Olathe it thickens locally to at least 50 feet. Northward from here it reaches to the bluffs along the Kansas and Missouri rivers, is the most prominent heavy limestone at the top of the bluff in Kansas City, and extends far to the north and east into the state of Missouri, passing below the railroad bed along the Missouri river at Connor. Its southeastern outcropping marks the crest of a row of bluffs from the south line of the state to the vicinity of Mound City, at which place the Thayer shales decrease in thickness to such an extent that the topographic features due to the Iola limestone coincide with similar ones produced by the Erie limestone. The distance to which this limestone extends beneath the surface can only be conjectured. The wells at Topeka and Fall River, the farthest west of any in the Carboniferous, show that it occurs in undiminished thickness, while every one in the intervening area shows the same fact.

In places the Iola limestone is very fossiliferous, producing the

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* Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 109; Lawrence, January, 1884.

following species with many others: *Michelinia eugeneac, Athyris subtilita, Lingula scotia, Productus longispinus, Productus pertenuis, Spirifera camerata, Spirifera lineatus, Aviculopecten carboniferus, Pinna subspatulata, Nautilus occidentalis, Nautilus missouriensis.*

THE CARLYLE LIMESTONE.*

Above the Iola limestone is a thin bed of shales with no marked characteristics and of but little stratigraphic importance. They have been described in both chapter IV and chapter VII. Above these we encounter the Carlyle limestone, which also has been mentioned in chapters III and VII. The northeastern limitations of this limestone have not been fully determined. At some places it seems to occur, while at others it is scarcely noticeable. From Iola northward to Kansas City, and thence up the Kansas river to Lawrence, a thin limestone system is found above the Iola limestone which corresponds in position and thickness very well with the Carlyle limestone, and quite likely it is the same, although exact correlations have not been made.

THE LANE SHALES.

Above the Carlyle limestone the Lane shales are next reached. These have been reviewed in chapters II, III, V, and VII, in the latter of which their extent and great stratigraphic importance has been particularly dwelt upon, so that nothing need be added here.

THE GARNETT LIMESTONE.*

Immediately above the Lane shales are two limestones separated by from 10 to 15 feet of shales. They appear in the bluffs at Argentine and from the upper limestone westward to Eudora, and have been passed by borings at Lawrence and Topeka. They cover the surface over a wide area along the Pottawatomie and Neosho rivers and northward to Eudora and Argentine, and extend southwest across the Neosho river and probably to beyond the limits of Kansas. North of the Kansas river they extend to Leavenworth, where they dip almost to the water's edge, and from here across the river to Plattsburg, Mo., and beyond.

*Haworth and Kirk: Kansas Univ. Quar., vol. 2, p. 110; Lawrence, January, 1894.

In places they thicken greatly. At the Lane "marble" quarries the upper one has reached the thickness of 30 or 40 feet, as it has also done about three miles east of Greeley. The most common invertebrate fossils found in them are the following: *Campophyllum* (?), *Fenestella* (?), *Synacladia biserialis, Derbya* (?), *Productus americanus, Productus semireticulatus, Syntrialasma hemiplicata* (very abundant in places), *Myalina kansensis, Myalina recurvirostris, Euomphalus subrugosus, Naticopsis altonensis, Pleurotomaria tabulata, Nautilus occidentalis*, and about 40 other species.

THE LAWRENCE SHALES.*

These shales in the vicinity of Lawrence are near 300 feet thick, if we let the name cover all lying between the Garnett limestone and the Oread limestone above. Occasionally a thin limestone occurs within them, one of which sometimes reaches 6 or more feet in thickness, but none of which have sufficient lateral extent to be of much consequence in stratigraphy. Southward from Lawrence they become thinner, so that along the Neosho river and to the south they gradually lose their great importance. Northward they maintain their thickness much better. They vary greatly in character in different places. They carry a prominent coal seam, which is mined extensively in Franklin county and to a lesser degree elsewhere, especially in Douglas county, and recently near Atchison. They carry a great deal of sandstone, but none of which is of a proper quality to be of much value economically. They are also particularly interesting on account of the large amount of arenaceous shales they have, almost all of which are filled with ripple marks and other indications of shore deposits. In fact, from top to bottom, they have such markings the most abundantly of any shales thus far passed. They also furnish excellently well preserved specimens of fossil coal plants.

The great thickness of the Lawrence shales produces marked physiographic effects. A great escarpment may be traced from Leavenworth far to the southwest of Ottawa, the bluffs of which are composed entirely of these shales, while an exceedingly rugged form is preserved by the protection of the overlying limestones.

* Haworth: Kansas Univ. Quar., vol. 2, p. 122; Lawrence, January, 1894.

THE OREAD LIMESTONE.*

Above the Lawrence shales are found two limestones averaging about 15 feet thick separated by about 20 feet of shale. They outcrop along the tops of the bluffs reaching from Atchison and Leavenworth to considerably south of Garnett, and take their name from Mount Oread at Lawrence. Westward they extend as far as any drill record has been obtainable. The upper one constitutes the main limestone in the bluffs at Lecompton and Atchison. Each is well filled with fossils, but particularly the upper one, from which 49 species were gathered in a few hours' time at Lecompton. The following is a partial list: *Fusulina cylindrica, Cyathaxonia distorta, Archiocidaris* (?), *Scaphicrionus* (?), *Chonetes granulifera, Derbya bennetti, Derbya broadheadi, Meekella striata-costata, Orthis robusta, Productus semireticulatus, Retzia mormoni* (large variety), *Strialasma hemiplicata, Allorisma regularis, Astartella* (?), *Avicula longa, Edmondia nebrascensis, Entolium avicula, Monoteria marian, Pleurotomaria bonharborensis, Nautilus sangamonensis, Paleocaris tipus.*

Above the Oread limestone is a bed of shale a little more than 60 feet thick, after which come the three Lecompton limestones exposed on the hilltop south of Lecompton. They are only a few feet thick and are separated by thin shale beds. Above them is another shale bed about 75 feet thick, the two thin limestones exposed at Tecumseh, another shale bed 50 or 60 feet thick, and then the three limestone systems which appear near Topeka. These are of little interest except from their position. Above them lies another shale bed 50 feet thick, at the top of which lies the Topeka coal, a seam about 11 inches thick which has been mined at different places. The coal is immediately overlaid by two thin limestone beds separated by less than 3 feet of shale.†

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* Haworth: Kansas Univ. Quar., vol. 2, p. 123; Lawrence, January, 1894.

† Since this volume started through the press, Mr. J. W. Beede, of Topeka, a young man fully capable of doing the work, has run a section to the southwest from Topeka, connecting the Topeka coal with the Carbondale-Burlingame coal, and has shown that the Topeka coal, and not that at Dover 100 feet above, should be correlated with the Carbondale-Burlingame-Osage City coal. The Dover coal is represented by a thin seam in the bluffs at Burlingame. This volume is therefore in error in a number of places where the Dover coal is correlated with the Osage City coal.—E. H.

OSAGE CITY AND BURLINGAME SHALES.*

Above the limestone mentioned are the Osage City shales, more than 100 feet thick, at the top of which lies the Osage coal, averaging 18 or 20 inches thick. Above the Osage coal is a thin limestone system, superseded in turn by the Burlingame shales, which are 150 feet thick in the vicinity of Burlingame, and possibly more in places. Both the Burlingame and Osage City shales extend long distances to the southwest and northeast and are important landmarks in stratigraphy. Another interesting feature of these shales is the great abundance within them of shaly sandstones and limestones carrying so many ripple marks and other indications of marginal deposits. Years ago Professor Mudge† discovered many reptilian tracks in the shaly limestones at the quarries near Osage City. He purchased two car-loads or more of the flagging stone on account of their carrying so many tracks, and shipped a large portion of them to Yale University, from which Professor Marsh‡ has recently identified them as being the tracks of ***Monopus caudatus*** and four or five other species. The Osage coal and the Osage City and Burlingame shales are particularly interesting on account of their evidence regarding the conditions which obtained at the time of their formation. There can be no doubt but that the marginal area and the ancient shore line gradually progressed westward from near the southeast corner of the state at the beginning of Coal Measure time until here we find them at least 120 miles farther away, during which period no less than 2,200 feet of Coal Measure deposits were formed.

THE WABAUNSEE FORMATION.§

Above the Osage City shales we have continuous sections of limestones and shales to the base of the Permian. Professor Prosser has proposed that the whole of this group lying below the Cottonwood Falls limestone be called the Wabaunsee formation, and would include within it the Burlingame shales above mentioned. The whole formation is similar in general character to those below,

* Kansas Univ. Quar., vol. 3, p. 278; Lawrence, 1895.
† American Jour. of Sci., vol. 6, 1873.
‡ American Jour. of Sci., vol. 48, pp. 81-84; New Haven, 1894.
§ Prosser: Jour. of Geol., vol. 3, p. 688; Chicago, October, 1895.

but there is a gradual transition in physical properties in both the shales and the limestones. The individual shale beds become thinner and gradually assume the peculiar lighter hue which must be observed in connection with the shales below in order to be fully understood. Here and there throughout the lower portion of the Coal Measures, it is true, beds of shale fully as light as those of the Wabaunsee formation occur, but they are interspersed with black bituminous shales, while in the Wabaunsee the latter are very rare. The limestones also take on a corresponding change. The beds are thinner than below, so that the alternations of limestone and shale are more frequent and the proportion of limestone is growing less. A peculiar light buff color creeps in so that the novice could readily distinguish between the greater portion of the Wabaunsee limestones and those below. This formation extends entirely across the state from north to south. It graduates into the conditions of both those above and below so that there are no sharp lines of demarkation, neither physical nor paleontologic. The thinning of the individual shale beds or the increasing, we might say, of the number of limestone shelves, introduces slightly different physical conditions, so that the general appearance of the surface of the uplands is not quite so rugged as may be observed farther east, but the various streams have cut their channels deep into the rocks and have left in some cases bluffs on either side reaching a height of from 200 to 300 feet above the valley of the stream. In this way the irregularities of the topography in the immediate vicinity of the drainage channel are fully as great or greater than that farther east, while the general upland conditions are more uniform, the escarpments which are visible being more mild.

Throughout the whole of the Wabaunsee formation only one limestone is of any special interest, the heavy coarse looking system lying about 30 feet below the Cottonwood Falls rock with which it seems to be entirely conformable. It is well illustrated in the section along the Neosho river and the Cottonwood river, and less perfectly along the Marais des Cygnes river and the Kansas river. Many large angular fragments are strewn along the sides of the bluffs below the formation, which in some places reach nearly 20 feet in thickness.

THE COTTONWOOD FALLS LIMESTONE.*

In our ascent from the base of the Carboniferous we finally reach the Cottonwood Falls limestone, a system which extends entirely across the state from north to south, and which is most remarkable on account of its great lateral extent and uniformity of characteristics, particularly so when we consider that nowhere throughout the whole area studied does it vary to less than 5 feet nor more than 10 feet in thickness. It is also remarkable on account of its association with an overlying shale bed which is so filled with invertebrate fossils of characteristic types that it can easily be recognized wherever found. The Cottonwood Falls limestone is further remarkable for its uniformity of both texture and color, and freedom from lateral and vertical seams. These make it an exceedingly desirable stone for building purposes, especially where large pieces are wanted. Quarries are operated in it in many localities, such as Manhattan, Alma, Eskridge, Americus, Cottonwood Falls Clements, and other places to the south. The limit in size for rocks obtained is only determined by the demand and the mechanical appliances for operating the quarries. The topographic features vary so greatly that the limestone is irregularly exposed to the surface over a belt twenty miles or more in width, reaching across the state from Manhattan southward. Thus its eastern outcropping, as given in chapter V, is at Eskridge, while the broad valley of Mill creek cuts downward to it twenty miles to the west. It approaches to within a few miles of Emporia and is again found at Clements, thirty miles to the west, with many quarries at intervening points.

THE COTTONWOOD SHALES.†

Immediately above the Cottonwood Falls limestone is a bed of light colored shales which will average about 14 feet in thickness. They seem to be co-extensive with the limestone and are characterized by the unusually great abundance of invertebrate fossils which they contain. In this way they at once become a most important stratigraphic formation, for their fossils permit their ready recog-

* This name is a common commercial term. Haworth and Kirk used it, Kansas Univ. Quar., January, 1894; Prosser uses the same "Cottonwood" for the same, Bul. Geol. Soc. Am., vol. 6, p. 40, and in Journal of Geology, vol. 3, p. 697, *et seq.*

† Prosser: Bul. Geol. Soc. Am., vol. 6, p. 40.

nition wherever observed. Together with the limestone they constitute the Cottonwood formation of Prosser.

CHARACTERISTICS OF THE COAL MEASURE LIMESTONES.

The Oswego limestones have been mentioned in different places as exceedingly compact and semi-crystalline throughout, and as particularly noted for their characteristic fauna. The lower one of the two in many places is one solid mass throughout, having no division into layers as limestones often have; further, it is characterized by slight impurities which render it valuable for the manufacture of hydraulic cement, the only limestone in the state thus far discovered possessing these properties in so marked a degree. The upper one, on the contrary, is more nearly normal in the matter of division into layers, but in many places is sufficiently crystalline to take a fairly good polish.

The Pawnee limestone as exposed in the vicinity of Fort Scott is massive in its nature and weathers into large blocks which are different from those of any other system observed in the state, and strongly resemble similar blocks seen along the bluffs capped by the Iola limestone. But a close examination of such boulders would determine at once that they differ from the Iola limestones in many respects. Both north and south from Fort Scott this massive character of the Pawnee limestone gradually disappears, so that it more closely resembles other limestones.

The Erie limestones in the vicinity of Uniontown are characterized in two particulars. One is the great abundance of flint nodules which they contain, particularly the middle system, as has already been described by Mr. Bennett. No place in the state is known to the writer, not even the flint beds of the Permian in the vicininty of Florence and Fort Riley, which carries a larger amount of flint nodules nor larger masses of flint than do these beds in places a few miles to the west of Portervale. The other characteristic referred to is the almost complete crystalline structure which the Erie limestones possess in places. There seems to be an association in some way between the degree of crystallization and the abundance of flint, so that near Uniontown the crystallization is highly developed.

The Iola limestone is remarkable in four ways: First, its great thickness; second, its great lateral extent; third, its unusual freedom from both lateral and vertical seams, and fourth, its high degree of crystallization. These points have all been referred to in preceding chapters. The freedom from either vertical or lateral fissures is so great that in the quarries at Iola immensely large blocks can be obtained which show no sign of fissures of any kind. This property is also recognizable along the outcroppings of the rock on the summits of the hills. The masses which break loose and begin working their way downward are remarkable for their great size. In many places such masses measure from twenty to fifty feet across, and doubtless in extreme cases, such as at Table Mound, they are even greater. In degree of crystallization almost throughout the whole of its extent within the state at least two-thirds of the mass of calcium carbonate exists in the crystalline state. This permits one to recognize it in many instances. In a few places only, such as around Fontana, does this crystalline structure decrease to normal conditions.

The Garnett limestones have characteristics which are of no special importance, excepting in the vicinity of Lane, where the Lane quarries occur. Here they assume a crystalline structure and a degree of compactness which render them unusually valuable for building material. Even more, they are susceptible of taking a high polish, so that they are serviceable for pedestals of tombstones, monuments, and other ornamental work. This property has given to them the title of "marble."

The upper one of the Oread limestones is noted for the large amount of flint which it carries, in some places almost equalling the ordinary proportion of flint in the famous Flint Hills limestone. It is also characterized as remarkably compact, as already pointed out, and is exceedingly rich in faunal contents.

In passing westward, shortly after leaving the horizon of Topeka, a marked change begins to be perceptible in both the limestones and the shales. The limestones begin assuming that peculiar buff color which is so characteristic of the Permian rock, a color which must be observed to be understood. In some of them this fades almost to a white, especially upon weathering. This is particularly true

of the Cottonwood Falls limestone, a rock which, as shown on the hillsides in the boulders broken from the ledges, seems to have an almost pure white color. The shales also begin parting with their dark carbonaceous or bituminous appearance and gradually grade into the lighter yellow or buff characteristic of the Permian shales. In this way the physical change is gradual, so that there is no sharp division line in the general characteristics of the Upper Coal Measures and of the Permian formations.

The various limestones above Topeka need little description until we come to the heavy limestone about 30 feet below the Cottonwood Falls rock, which is the dry-bone of Swallow. This one has a very characteristic appearance, so that it usually may be recognized quite readily. Being so heavy it has been an important factor in producing the physiographic conditions, therefore it is prominently exposed along the bluffs in many parts of the state. The term "dry-bone" was evidently applied by Swallow on account of the rough porous surface produced by weathering. In some way portions yield to the weathering agents much more rapidly than others and by dissolving out leave a coarse honeycombed texture for the whole mass. The color of the rock, also, is darker than those either above or below, so that it presents a prominent appearance on the hillsides.

The Cottonwood Falls rock has already been described so well that little need be addded here. It weathers white, more so than any other rock known in the sate. It is slightly porous throughout the whole mass, and it almost universally carries large quantities of *Fusilina-cylindrica,* with but few other fossils. In places considerable quantities of flint are found, enough to seriously interfere with the dressing of the stone, but this is not generally the case. The most prominent feature, perhaps, of this rock is the unusual absence of vertical fissures within it. This is true to so great an extent that blocks of any desirable size can be obtained. It is no exaggeration to say that masses hundreds of feet in extent could easily be taken out which would be entirely free from vertical fissures. The softness of the rock, which permits it to be sawed with ease, the color of the rock, which makes it desirable for whole structures or for trimmings in brick buildings, and the unusual freedom from fissures,

combine to make the Cottonwood Falls limestone the most valuable rock known in the state, while its unusually great geographic extent brings it within the easy reach by rail of all parts of eastern Kansas and adjoining territory.

CHARACTERISTICS OF THE COAL MEASURE SANDSTONES.

The Carboniferous sandstones are exceedingly variable and uncertain; the ease and frequency with which they grade into the shales and back again into sandstones is noticeable on every hand. As has been stated, this property is so marked that for stratigraphic purposes they are practically useless. In only a few places can any particular sandstone formation be traced in a northwest and southeast direction exceeding ten miles. The most noted of these exceptions is in the vicinity of Redfield and Farlington where the great flagging-stone beds occur over so wide an area. The conditions of these flags show that they were formed in marginal areas not far from shore.

The sandstones in the Cherokee shales in most cases are in thin layers producing good flagging stone. This is well represented in the southeast corner of township 33 south, range 24 east, in Cherokee county, at the quarry operated by Mr. Riley Burrass. Here it would seem there is no limit to the flagging stones which may be obtained. Some of them are less than 2 inches thick, while others are from 6 to 10 inches. They can be obtained of any desirable dimensions, even to extreme lengths. Above this bed of flagging stone perhaps a hundred feet or more the Columbus sandstones are reached, the most striking characteristics of which are the thick layers in places and the thin layers in other places. At the quarry of Esquire Willey, about two miles west of the Burrass quarry, flagging stone similar to those just mentioned may be obtained in great quantity and of any desirable thickness from 1 inch up to 6 or 8. Yet within less than a mile of this particular place, and on the same hill, at the Townsend quarry, the sandstone thickens in layers so that blocks 10 to 20 inches thick or even more can readily be obtained, while the thinner layers are entirely absent. Such variations of condition characterize the Columbus sandstones, so that in

still other instances the thin flagging stones may be obtained at one point, and a few miles away the heavy building stones.

But the most remarkable flagging stones in the state, perhaps, are those in the Pleasanton shales above the Pawnee limestone in the vicinity of Farlington, Redfield, Gilfillan, west of Fort Scott, and still farther west along the Neosho river. Here flags of unsurpassed quality and quantity can be quarried.

The Thayer shales carry sandstones at various places, but principally near their summit. In general they are in heavy layers, so that they are serviceable for building purposes. This is well illustrated in the vicinity of Thayer and Neodesha. Lower down in the shale beds are vast quantities of sandstone in the vicinity of Independence. The greatest objection to the sandstones in the Thayer shales is that they are somewhat deficient in cementing material and thereby lack the firmness of first-class building stone.

In the Lane shales we have another instance of great sandstone deposits having been produced. These are most marked in the vicinity of Burlington and to the southwest. But here the topographic features show conclusively that there was no persistency of sandstone deposits over any considerable area. A sandstone hill here, a valley there, and a hill again beyond can only be accounted for, in the absence of other evidence, on the assumption that the valleys mark locations where the sandstones had graded into arenaceous shales, or in some way had assumed properties which made them yield more readily to erosion.

Above the Garnett limestone we have another great shale bed, the Lawrence shales, with many included sandstones. These to a much greater extent than any studied below them have ripple marks and rain-drop marks occurring with wonderful frequency. No sandstone bed has ever been examined by the writer which contained more conclusive evidence of having been produced in shallow water than these. Not a single instance is known in which a sandstone has any commercial value, for they are friable, argillaceous, unevenly bedded, exceedingly variable in texture, and have many other properties which deprive them from possessing value as building stone.

Passing upwards from here in the vicinity of the Osage City coals

we have another great shale bed with many sandstones and calcerous shales interspersed, all of which bear evidence of being produced in shallow water. The Wabaunsee formation has but little sandstone and that which it does possess is noted for the thinness of the layers, the weakness of the cement, and the unreliability of its continuation in lateral directions. In fact it can rarely be called more than arenaceous shales. This is true to a still greater degree with the Permian, which has essentially no sandstone whatever.

CHARACTERISTICS OF THE COAL MEASURE SHALES.

The Kansas Coal Measure shales do not differ essentially from Coal Measure shales in other parts of America. In places they are exceedingly bituminous with the black color resulting therefrom, while perhaps vertically no more than 20 feet away they will have a light ashy color, as though almost no carbonaceous material was contained within them. The numerous beds of coal which they carry that are of workable extent show how exceedingly rich they are in carbon. To these should be added no less than a dozen or twenty smaller veins of much less extent laterally which attract but little attention. Perhaps more than half of the Cherokee shales are light colored, and consequently the soils produced therefrom, which cover so large a portion of Cherokee and Crawford counties, are likewise light in color. Such soils are generally exceedingly fine grained because the shales from which they are produced are also fine in texture.

The readiness with which the shales and sandstones grade back and forth into each other has already been mentioned. It is difficult to estimate what fractional part of the volume is sandstone, but perhaps not less than a fifth.

Near the summit of the Cherokee shales a few feet below the Fort Scott coal we find an unusually hard and black shale filled with small concretions in the interior of which usually one finds a little shell. These are so nearly identical with the bed of shales lying between the two Oswego limestone systems that they cannot be distinguished. They are wonderfully persistent in their black color and concretionary inclusions throughout the whole distance from Oswego to Fort Scott and probably very much farther. Also in this

same shale bed we find the oddly shaped calcareous concretions described and illustrated by Mr. Bennett in chapter IV, a peculiarity which is almost entirely unknown everywhere else in the Kansas Coal Measures.

In many places throughout the Cherokee shales strata are found which have the proper chemical and physical qualities for the manufacture of vitrified brick. This is well illustrated at Pittsburg, where brick are manufactured to so great an extent. The particular clay shales used at this point are no more favorable for the production of vitrified brick than other shales which could be found in a hundred different places.

The shale beds lying between the Oswego limestone and the Pawnee limestone have few characteristic features. In some places they are exceedingly bituminous, while in others, removed only a short vertical distance, they assume a light ashy color. Near their summit in the vicinity of Prescott they are well filled with small concretions having small brachiopod shells for nuclei, which make them strongly resemble members of the Cherokee shales.

The Pleasanton shales are most noted, perhaps, for the flagging stone which they contain. The easy gradation from sandstone to shales and from shales to sandstone is here carried to a great extent. The color of the Pleasanton shales is variable. Some of them are coal black with a large percentage of contained carbonaceous matter, while others are light in color. Good sections of these shales can be had at the bluffs at Boicourt and along the bluffs north of La Cygne, as well as at Mound City and many other places.

There is nothing specially characteristic in any of the shales observed upwards from here to the Lawrence shales. Here the excessive amount of arenaceous and shaly sandstones has already been mentioned with their ever-prseent ripple marks and rain-drop marks and other characteristics showing that they were formed in shallow water. Near the top of the Lawrence shales are two beds of clay shales, which are prominent in the hills in the vicinity of Lawrence. The principal one, about 3 feet thick, is light lead gray in color, and is found about 6 feet below the bottom of the Oread limestone. It seems to be void of stratification within itself, but in places is filled with fissures cutting diagonally across it. It is wonderfully

plastic, has enough iron present to render it easily fusible, and possesses many of the characteristics of the best clay shales. Again, only a few feet below this is another bed of about equal thickness of red clay shales. These have other physical properties practically identical with the blue shales above mentioned. They are the most plastic shales known, and would doubtless make excellent vitrified brick.

The shales lying between the two Oread limestones are light yellowish-green in color, and in places have many small concretions similar to those so noted in connection with the Oswego limestone, although, so far as observed, they do not contain fossil shells as nuclei. In the vicinity of Topeka the shale beds are used as a source of clay for the vitrified brick manufactured by the Capital City Brick Company, and are found to be satisfactory in every respect. Passing upward from this place no special features are observable throughout the greater part of the Wabaunsee formation, excepting the gradual change of color already alluded to. In the vicinity of Manhattan, just below the Cottonwood Falls limestone, a bed of red clay shales is relatively prominent, recalling in general appearance the red member of the Lawrence shales. Its exact thickness has not been determined, as no fresh excavations were found, and the red material in working its way down the hillside is so misleading that one is hardly safe in estimating the thickness of the stratum from such outcroppings.

COAL MEASURE SHALES PRINCIPALLY SUB-MARINE IN ORIGIN.

There is no fundamental reason why great shale beds may not have been formed under great fresh-water lakes, or fresh-water lagoons of varying depths. The shales in the Coal Measures of Kansas, however, probably were principally deposited under salt water. Two general reasons have led to this conclusion. The first is the great frequency throughout almost all of the shale beds of traces of calcareous matter. Many little limestone layers are found which vary from 2 to 10 or 12 inches, and which rarely are sufficiently pure to be called limestone. Such formations generally have well preserved marine invertebrate shells within them, showing that they were formed under ocean water. Were all of such forma-

tions counted within the Cherokee shales, they would probably reach 20 or 30. In other shales similar conditions obtain, so that the great mass of Coal Measure shales either were principally deposited under ocean water or the number of emergences and submergences were manifold greater than the estimates given in the earlier pages of this chapter.

The second reason for believing the Coal Measure shales were deposited beneath ocean water is the great frequency of salt water within them. Not a single instance is known to the writer of water having been obtained at a depth equal to or greater than 200 feet within the shales which was not more or less salty. With the recent extensive prospecting for oil and gas many dozens of wells have been drilled, so that the test can be made quite thoroughly over the area prospected. Farther to the west the conditions in this respect seem to be about the same. The deep well at McFarland produced abundance of salt water, while according to Hay* those of St. Mary's and Wamego seem to have pierced 3 or 4 feet of rock salt. The same author states† that at La Cygne 80 feet of rock salt was passed in a deep well. This matter was investigated and the conclusion reached that there was no satisfactory evidence of the existence of rock salt anywhere within the shales passed by the well, but that the production of strong brine here was similiar to that in so many other wells. However, the presence of rock salt would only add strength to the argument here deduced. It is difficult to understand why the salt water would be so universally obtainable over an area so many hundred square miles in extent, excepting by assuming that the shales were deposited under salt water and retained a portion of the same, the salt of which has since been dissolved by percolating waters and is brought to notice when the wells are drilled. As almost every shale bed in the Carboniferous has produced either rock salt or salt water, the argument is applicable to all of them.

INCLINATION OF THE COAL MEASURE STRATA.

With a few local exceptions all the formations of the Coal Measures dip westward. The Mississippian floor, as already shown in the early pages of this chapter, has its maximum westward dip

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*Geology and Mineral Resources of Kansas, 1893, p. 43.

† *Loc. cit.*, p. 43.

along the south line of the state where the inclination reaches more than 20 feet to the mile. The overlying formations are essentially conformable to the upper surface of this floor. The examples of nonconformity between the Coal Measure formations and the Mississippian, which have been most carefully studied, are confined to the eastern border of the Coal Measures. This is true not only in Kansas but in Missouri and Iowa as well. The existence of such nonconformities therefore may perhaps be looked upon as due to surface erosion of the Mississippian previous to the Coal Measure period. We cannot study such nonconformity farther west in detail, so we are left in doubt regarding the westward extent of such surface erosions. Possibly they reach all over the area where the Mississippian rocks are known to exist; possibly for only a short distance in that direction. But a study of the various sections accompanying this report shows conclusively that the Coal Measure formations in general have an inclination which in direction and magnitude corresponds very closely with the surface of the Mississippian formations. As we advance in the column generally we find the inclination slightly decreasing. The great thickening of all the formations to the southwest as already described would render the inclination of the upper strata less marked than that of the lower. When we come to the vicinity of Kansas City, however, we find there has been a general thickening among the upper formations towards the north. This is prominently noticeable in the Lawrence shales, and by that means there has been to a certain extent an evening up of the original inclinations slightly altered by the above-mentioned thickening to the southwest lower down. The section along the Kansas river shows an average inclination of from 12 to 14 feet to the mile. The section along the Missouri river from Kansas City to the Nebraska line shows even a greater inclination in that direction. Yet it must not be understood that the general dip of the formations for the whole of eastern Kansas is the greatest in the northwest direction, for such certainly is not the case. It would seem there is a ridge or a dividing line trending from the southeast part of the state towards the northwest on the southwest side of which the maximum inclination is southwest and on the northeast side of which the maximum inclination is to the northwest.

Aside from the general dipping of the strata there are many local dips, anticlinals and synclinals, which may be of considerable importance in studying the stratigraphy at any special locality. Some of these have already been pointed out in the preceding chapters and illustrated in the different plates already referred to. One notable example of this is just north of Fort Scott where the Oswego limestones rise forming an anticlinal ridge of decidedly pronounced class. Northward from the Fort Scott cement works the roadbed of the Kansas City, Fort Scott & Memphis line follows the upper surface of the limestone rising in one of the heaviest grades along the line. Another anticlinal ridge lies south of Fort Scott on the high divide between Fort Scott and Girard. Here the anticlinal extends over several miles and is much less pronounced locally than the one just described. At a few places, however, the inclination is tolerably great. About a mile south of Englevale the Oswego limestones with the underlying Fort Scott coal dip to the north a hundred feet to the mile. Beyond the ridge to the northeast of Girard at one place on the upper part of Cow creek measurements were made where a similar formation dipped to the southwest at fully as high an angle. Mr. Bennett has called attention to a similar anticlinal ridge north of Doniphan. The high divide between Doniphan and Highland is so covered with glacial deposits that the limestones could not be traced throughout the whole distance. But on the south side of this divide the rocks dip to the south while on the north side they dip to the north, leaving little ground for doubt that the existence of this high ridge is partially due to this long gentle anticlinal. Similarly the rocks to the south of Cherryvale dip to the south and southwest more rapidly than the average dip for the same formations. It has not been determined whether beyond this to the north they have a northeast inclination or not, but probably they have, at least to some degree. The most prominent fold in the whole Carboniferous of the state is found on the Cottonwood river just west of Strong City. It affects the Cottonwood Falls limestone and the "dry-bone" limestone below very strongly. Passing westward from the stone quarries in the vicinity of Cottonwood Falls the limestone dips rapidly until it disappears below the surface about two miles up the river. For another span of nearly two miles

it is not visible on either side of the river, when suddenly it with the "dry-bone" 30 feet below it and the included shales rise rapidly to the west and ascend to the hilltop just east of Elmdale Mills where they occupy a position higher than they attain on the hills six miles to the east. On the north side of the river along the bluffs two distinct anticlinal ridges are noticeable. The inclination on the sides of this synclinal trough in places reaches almost to 4 degrees, with probably an average of from 2 to 2.5 for the whole of the western side. This is represented in plate III of the section along the Cottonwood river.

These illustrations may be taken as examples of what one may expect all over the Coal Measure areas: low anticlinal ridges and synclinal troughs with sufficient inclinations to be readily observable, yet of so low an order and so limited in extent that they do not materially affect the general westward inclination of formations.

The most common direction of the anticlinal and synclinal axes is from the northwest to the southeast, or approximately at right angles to the line of outcropping of the different formations. Considerable effort was made to determine the cause of these various irregularities. In some instances the conclusion was reached that the primary cause was due to the inequalities of the ocean bed on which the deposits were formed. In the production of ocean beds one can readily understand how a slight inequality in the distribution of shale forming materials would leave an uneven surface for the limestones which succeeded it, and that correspondingly a lack of regularity in the production of calcareous matter would equally produce an irregularity of the limestone for the shale beds to rest upon.

FAULTS IN THE COAL MEASURES.

A few faults are known within the Coal Measures, but none of any considerable extent. The Cherokee shales have numerous faults, with vertical displacements sometimes reaching 18 or 20 inches, as was mentioned in chapter II. The Lawrence shales likewise have some such faults. One is positively known to exist in the vicinity of Sibley. Mr. Bowman, while following a 14-inch seam of coal a few feet under the surface, was surprised to find that it suddenly disappeared. By digging downwards about 3 feet, however,

he came upon the same coal bed which had been displaced to that extent. It is quite probable that detailed investigations throughout the Coal Measure area will detect many similar faults and possibly even greater ones, although the almost perfect harmony of stratification as shown along the lines of the different sections heretofore described, sections which cross each other in so many different places, and which trend in so many different directions, would seem to positively establish the absence of any very considerable faults throughout the whole Coal Measure area.

Neither is there any considerable evidence of regional or dynamic metamorphism anywhere within the Coal Measures of the state. Only one locality has been found which at all approaches anything of this nature—the once famous "silver mines" in Woodson county. Diligent search was made by all the observers in every locality for marks or traces of metamorphism of any kind, or any other indications of disturbances of volcanic or eruptive nature, but nothing whatever was seen.

RATIO OF COAL MEASURE LIMESTONES TO SHALES AND SANDSTONE.

In the whole Coal Measures the limestones aggregate about 540 feet, which gives a ratio of limestone to total thickness of 1 : 5. In the Lower Coal Measures there are only about 81 feet of limestone, or a ratio of 1 : 10; while in the Upper Coal Measures there are about 460 feet of limestone, giving a ratio of 1 : 4.2. It will be noticed that the largest amount of limestone relatively is near the middle of the Coal Measure column. Beginning at the base of the Lawrence shales and going downward to the Pleasanton shales we have a little more than half the vertical distance occupied by limestone. (See plate XXII.) The great bed of Cherokee shales at the base of the Coal Measures and the relatively large amount of shales in the Wabaunsee formation seem to correspond tolerably well in amount, yet there is not a very strong similarity between the two classes of rock.

THICKNESS OF THE COAL MEASURES.

The thickness of the Kansas Coal Measures cannot be much if any less than 2,600 feet. In the general section, plate XXII, it is represented as amounting to a little over 2,750 feet, but in it the average thickness is given as it is known. As some of them, particularly the Thayer, the Lane and the Lawrence shales and the Independence and Iola limestones, are known to have different thicknesses in different parts of the state, it is presumable that no one point could be found at which all of the various formations would have their average thickness. However, at Cherryvale the known thickness from the top of the hills is a little over 1,100 feet, while the general section gives it as 950 feet. Westward in the vicinity of Elk City, as Adams has shown in chapter I, the total thickness from the bottom of the Oswego limestone to the top of the Iola is over a thousand feet, while in the general section it is given at 745 feet. A similar condition is shown from the records of the Fall River well. The known thickness from the valley here is 1,405 feet, while in the general section only 1,300 feet are given. At Kansas City the known thickness from the hilltops is a thousand feet or more, and that given in the general section is but a little over 1,100. At Topeka, 110 miles from the southeastern limit of the Coal Measures, the known thickness below the hilltops is 1,750 feet, and the well did not reach the bottom. In the general section the thickness is given here as 2,050 feet. The McFarland well, starting from the valley, reached a depth of 2,006 feet, or a depth of fully 2,150 feet below the Cottonwood Falls limestone. From the character of the record, as best one can judge by careful comparison of it with the known conditions farther to the southeast, one is led to conclude that it has only penetrated the Cherokee shales about 200 feet. Should these shales be as thick here as they are at Topeka, it would make a thickness of 2,650 at this one point from the Cottonwood Falls rock to the base of the Coal Measures. There can be no reasonable doubt, therefore, that many different places can be found in the state where a well would have to reach a depth of over 2,600 feet in order to pass entirely through the Upper and Lower Coal Measures. The estimate given in the general section is therefore not very far from correct,

while the probabilities are in the Flint Hills area, judging from the uniform thickening of all the formations to the southwest, the total thickness of the Coal Measures may be considerably more than the numbers therein given.

DIVISION OF KANSAS COAL MEASURES.

So many different plans have been followed by geologists of the Mississippi valley in dividing the Coal Measures that one who is laboring in a new field has no positive criterion by which to be guided. By some the Coal Measures have been divided into two divisions, the Lower and the Upper; by others into three, the Lower, Middle, and Upper. Rarely have the same division lines been made, or the same basis of classification been used, so that we are left in doubt in almost all instances why any particular division was made at any particular place. According to the different state reports of our nearest neighbor to the east, Missouri, Broadhead used a sandstone with no special characteristics as the division line between the Lower and Middle Coal Measures, and a second sandstone of equally unimportant characteristics for the division line between the Middle and Upper. Why these particular sandstones should be chosen rather than other formations he does not say, neither are we informed why the whole Coal Measures should be divided into three divisions rather than into two, or four, or any other number. Winslow, in his more recent report, does not attempt to divide the Missouri Coal Measures at all, but he does not take grounds against it, so the reader is left in doubt to a certain degree regarding his views on the subject. But Doctor Keyes, in volumes I and II of the Iowa reports, brings up strong objections to the older method of division, and suggests what seems to him a better basis of division, provided one is used at all. We shall have occasion to refer to this later in this chapter.

It would seem reasonable to assume that in all matters of divisions and subdivisions of the Coal Measures the same general methods should be adopted and the same principles followed that are used in determining the number and locations of the subdivision lines of any other great geologic formation. The custom of geologists of all countries is practically the same in this. At least

one of two conditions is always required to make a division which in application is more than local. One of the conditions is that there must have been a break in the succession of formations—a time break, indicated by general nonconformity, such as is produced when a surface is lifted above ocean water and more or less eroded before later formations are subsequently placed upon them, or when considerable orographic movement has occurred, leaving the strata already formed in an inclined position, so that the new formations will not be conformable with them.

The other condition accepted universally as a sufficient basis for making a division or subdivision in stratigraphy is a positive variation of any character in the flora or fauna of the formations concerned. There may be grounds for difference of opinion, or difference in custom regarding the degree of variation which should obtain, but all admit that if the change is sufficiently great a division of the formation should be made, either with or without nonconformity.

As has already been shown in this chapter, the Coal Measures of Kansas are 2,750 feet thick, and cover an area of approximately 20,000 square miles. It would seem desirable, therefore, for the sake of convenience, to subdivide them into two or more groups. But when a section of country has been studied in sufficient detail to trace the different great classes of formations across the whole area, and to determine their limits vertically, as has been done for the Kansas Coal Measures, through the assistance of the numerous deep wells which have recently been drilled in our state, it becomes possible to make many subdivisions to which local geographic names can be applied, thereby in great measure limiting the convenience which may be derived from other kinds of subdivisions. It is doubtful whether any real convenience will arise by making any divisions of our Coal Measures other than those already made and to which local geographic names have been assigned, for it is now possible to speak exactly with reference to any portion whatever of our Coal Measures anywhere in the state by a proper use of the terms already introduced.

It is the concerted opinion of the different individuals who have been engaged in field-work preparatory to this report that the

Kansas Coal Measures should be divided into two divisions, which may be designated as the Lower and the Upper. Careful search failed to discover any considerable nonconformity anywhere throughout the entire distance between the Cherokee shales and the Cottonwood Falls limestone, although, as has already been pointed out, slight nonconformities exist everywhere. The uppermost members of the Coal Measures are quite different from those situated at the base, but the transitions of all physical properties seem to be gradual rather than abrupt. This gradual change is shared by the coal itself. The variations in lithologic characters are mere repetitions, from limestone to shale and sandstone, and then back to limestone again. It is apparent to every member of the Survey that unless the change from shale to limestone or limestone to shale would warrant a division, nothing in the line of physical properties throughout the whole Coal Measures could be used as a basis. But when we turn to the side of palaeontology we are not so wholly deprived of variations. The great familiarity Mr. Bennett has possessed for years with the invertebrate fauna of the Coal Measures of Iowa, Missouri, Kansas and the Indian Territory made it an easy matter for him to point out a horizon at which there was a considerable abruptness of faunal variation which seems to be sufficient to warrant a division of the Coal Measures.

According to palaeontologic evidence obtained by Mr. Bennett there is quite a decided faunal change at the top of the Pleasanton shales. One species, *Chonetes mesoloba,* and probably more, which is very abundant and widespread below this line cannot be found above it anywhere in the state. Not only this, but other species first appear in the Erie limestone, making a decided change of species in the invertebrate fauna. This faunal change is accompanied by as great physical changes as can be found at any line. It has the great bed of the Pleasanton shales below it and the Erie limestone group above it, each of which has been traced entirely across the state from Kansas City to the south line. In addition to this, as has been pointed out earlier in this chapter, the same two formations reach, according to Broadhead, from Kansas City northwards to the border of Iowa, the lower member of the limestone series being known as the Bethany Falls limestone, No. 78 of Broadhead's general section.

They also extend in undiminished thickness to the west under the surface as far as can be determined by the various deep wells, with no reason for doubting their uninterrupted extension for a hundred miles or more beyond.

To sum the matter up in a few words, it is proposed to divide the Coal Measures of Kansas into two divisions, to be designated by the terms Lower Coal Measures and Upper Coal Measures,* the division line to be placed at the top of the Pleasanton shales, which is at the bottom of the Erie limestone, the basis of division to be principally palaeontologic and dependent upon the disappearance of the species of the brachiopod fossil, *Chonetes mesoloba,* and upon the first appearance of different species in the Erie limestone above, but also partially dependent upon the great physical change which marks the line between the two extensive and characteristic formations, the Pleasanton shales and the Erie limestone.

This division does not correspond with either one used by Broadhead for the Missouri Coal Measures. His division between the Middle and Upper is a sandstone situated a little below the Bethany Falls limestone and therefore a little below the line here proposed. Why Broadhead should have chosen sandstone to mark his division line cannot be understood, for, at least in Kansas, all the Coal Measure sandstone is so limited in its extent that it can be used for no lines of demarkation whatever, excepting for the most local divisions.

In his excellent report of the coal deposits of Iowa, Dr. Keyes† has adopted in a general way the principles first enunciated by Winslow.‡ They assume that throughout Coal Measure time there was a gradual but irregular subsidence of both the ocean bottom and land areas under the Coal Measure areas, and that the subsidence occurred principally near the shore lines, so that as fast as the sedimentation from the land area would bring the new formed strata to near the surface additional subsidence would occur. In this way a continuous series of marginal formations would be pro-

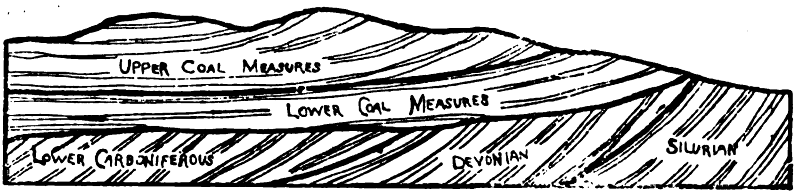
* Doctor Keyes has laid aside the older terms "Lower" and "Upper," and substituted the geographic terms "Des Moines" and "Missouri" for what seems to be practically the same general division. As local terms they are admissible, of course, but for general terms priority would hardly admit their use until it has been shown that the older terms were in some way disqualified.

† Iowa Geol. Surv., vol. 2, 1894.

‡ Missouri Geol. Rep. Coal, 1891, pp. 21-32; also Bul. G. S. A., vol. 3, pp. 109-121.

duced, the older of which would be farther oceanward than the younger. Keyes has gone farther than Winslow, and has suggested that the natural division of the Coal Measures would be a line running diagonally to the stratification, placing all of the marginal areas in one group and the deep-sea areas in another, as represented by figures 9 and 10 on page 162 of his report, which are here reproduced, figures 7 and 8.

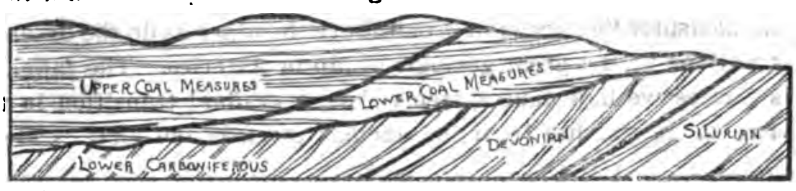
Figure 7.



Popular idea of the relations of the Lower and Upper Coal Measures. (After Keyes, Iowa Geol. Surv., vol. 2, p. 162.)

The conditions in Kansas will not admit of such a classification for the following reasons: First, according to the Keyes explanation, the later and consequently younger marginal areas would be landward from the earlier and older. But we have undoubted evidence that the land area for Kansas in Coal Measure time was the Mississippian to the southeast, while the later marginal areas are now found much farther to the west, as is illustrated by the Osage City shale beds and coal, which are from 100 to 120 miles west of the present western exposure of the Mississippian formation and almost as great a distance oceanward from the earliest marginal areas. Second, the universal westward thickening and eastward thinning of all the formations, as argued by

Figure 8.



Actual relations of the Lower and Upper Coal Measures as now understood. (After Keyes, Iowa Geol. Surv., vol. 2, p. 162.)

Winslow, and pointed out in this chapter, is of such a nature that we cannot admit the earlier existence of the Coal Measure formations very much farther to the southeast than their present limits, so that we cannot account for the marginal formations in the various places where they are known to exist in such widely scattered localities without assuming that there was a relative elevation of the coastal areas rather than a continual subsidence, as Keyes assumes. The Cherokee shales are marginal in their character, so are the Pleasanton shales, the Thayer shales, the Lawrence shales, and the Osage City shales, each in turn being located continually farther oceanward and upward from the position occupied by the coast at the beginning of Coal Measure time. There is a strong parallelism between this and the relative positions of the outcroppings of the great geologic formations of America which are universally explained on the assumption of a gradually rising continent or a gradually subsiding ocean bottom. Third, one cannot make a careful study of the accompanying plates which represent sections run in so many different directions across the Coal Measures, and which for the representation of underground stratification are entirely dependent upon accurate records of so many deep wells, without admitting that each of the great formations, both shale and limestone, are continued uninterruptedly far to the west. Fourth, any division plane of the Coal Measures which would pass diagonally to the stratification of the formations would be unnatural and would correspond in principle to passing a plane diagonally to the stratification lines which separate the Silurian from the Devonian, or the Devonian from the Mississippian. All of these latter great formations have portions within them which were marginal in origin and others which were formed under deeper ocean. But no one would entertain the thought of basing the greater classifications on such properties as these. The different formations in the Kansas Coal Measures lie as regularly one above the other as do the different formations in any great geologic group in America. The fauna of the successive limestone systems show a gradual transition in the forms of animal life from the ancient towards the more modern, which strongly indicate that all of any one limestone system is older than those above it and younger than those below it. A divi-

sion plane which would cut these diagonally would therefore be at variance with the accepted rules of time classification.

For all these reasons, and others which might be added, it seems that it is both unnatural and undesirable to divide the Coal Measures of Kansas otherwise than by a method at least similar to the one herein adopted.

C.—THE PERMIAN.*

In the division of the Upper Carboniferous of the state considerable diversity has obtained in the usage of different geologists. Swallow places the base of the lower Permian at his number 84, the "dry-bone" limestone, already described in the Coal Measures. Meek and Hayden† are inclined to place the base of the Permian much higher than Swallow has done; while some geologists, notably Newberry,‡ are inclined to discredit the existence of the true Permian in America. It has also been suggested by some that a portion of the beds, the faunal contents of which are partially Coal Measure and partially Permian in character, be designated as Permo-Carboniferous, leaving only a relatively small portion of the Upper Carboniferous to be called the true Permian. Prosser§ has recently given an excellent and exhaustive discussion of the subject based upon two summers of field work in Kansas. It is probable his conclusions are more reliable than those of any other writer on the American Permian, for he has devoted much more time to the field work than others have been able to do, and therefore he will be followed in this short discussion.

According to Prosser, the Upper Carboniferous of Kansas may be divided into two great groups, the Upper Coal Measures and the Permian, leaving out entirely the Permo-Carboniferous. He places the base of the Permian at the top of the Cottonwood formation, that is, at the top of the 14-foot shale bed immediately overlying the Cottonwood Falls limestone. The areal limitations therefore between the Upper Coal Measures and the Permian may be looked upon as corresponding with the eastern extension of the Cottonwood

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* Swallow: Prel. Rep. Geol. Surv. of Kas., p. 16; Lawrence, 1866.

† Meek and Hayden: Proc. Acad. Sci. Phila., vol. 11, pp. 8-30; Philadelphia, 1859.

‡ Newberry: The Work of the International Cong. Geol., 1886, p. 29; also, Am. Jour. Sc. (3), vol. 30, p. 469; New Haven, 1885.

§ Prosser: Classification of the Principal Paleozoic Rocks, Jour. of Geol., vol. 3, pp. 682-705, and 764-800.

Falls limestone and is represented in this way upon the geological map accompanying this Report. Within the Permian Prosser makes the following divisions: First in the ascending order, the Neosho formation, reaching from the Cottonwood formation to the first general flint beds so well represented near Strong City and Fort Riley, the Wreford limestone of Hay in the Fort Riley section, figure 6 of this Report, and the fifth cherty limestone of Swallow, number 62, or the limestone No. 18 of Meek and Hayden. The total thickness of the Neosho formation is given as 130 feet. Next above this he places the Chase formation, passing from the bottom of the flint beds just mentioned to the Marion concretionary limestone, a distance of 265 feet, and above this 400 feet to the top of the Carboniferous, which he calls the Marion formation, making an aggregate of 795 feet of Permian for Kansas.

TABLE showing the stratigraphic position and character of the formations comprising the upper Palæozoic of central Kansas.—*After Prosser, Jour. of Geol., Vol. III. p. 797.*

Period.	Series.	Formation or stage.	Stratigraphic character of the different beds.	Characteristic fossils.	Thickness of beds.	Total thickness.	Thickness of formations.
Carboniferous.	Permian.	Marion (Prosser).	Variously colored shales and marls. Colored shales and marls alternating with beds of gypsum. Buff limestones and marls.		250±	1390	400±
			Abilene conglomerate.		20±	1140	
			Shaly buff limestones with *Pleurophorus.*	*Pleurophorus subcuneatus, Bakevellia parva, Edmondia calhouni, nucula sp.*			
			Buff limestones which contain large *Lamelibranchia.*	*Aviculopecten occidentalis, Myalina permiana, Pseudomonotis Hawni.*		1120	
			Grayish (?) limestones containing plenty of *Bakevellias*, near this horizon in some localities a concretionary limestone. Thin buff limestones with a few *Derbyas*.	*Pleurophorus subcuneatus, Bakevellia parva, Schizodus curtus, Schizodus ovatus, Nautlus eccentricus, Yoldia subscitula.*	130		
		Chase (Prosser).	*Marion concretionary limestone;* containing large brown concretions.	*Athyris subtilita, Productus semireticulatus, Derbya multistriata.*	10	990	
			Yellowish shales, free *Brachiopods*.	*Athyris subtilita, Productus semireticulatus, Derbya crassa, Septopora fiserialis.*	13+	980	

TABLE SHOWING THE STRATIGRAPHIC POSITION, ETC.—*Continued.*

Period.	Series.	Formation or stage.	Stratigraphic character of the different beds.	Characteristic fossils.	Thickness of beds	Total thickness	Thickness of formations.
Carboniferous.	Permian.	Chase (Prosser.)	*Marion flint*; light gray limestone, generally containing flint.	*Productus semireticulatus*, var. *Calhounianus*, *Athyris subtilita*, *Archaeocidaris* sp.	4	967	265
		Chase (Prosser).	Variously colored shales with thin layers of limestone.		62±	963	
			Buff shaly limestones with *Lamellibranch* fauna.	*Bakevellia parva*, *Pleurophorus subcuneatus*, *Aviculopecten occidentalis*.	22	901	
			Fort Riley or *Florence limestone*; a massive buff limestone.		+	879	
			Buff shaly limestones containing an abundant *Brachiopod* fauna.	*Derbya multistriata*, *Athyris subtilita*, *Productus semireticulatus* var. *calhounianus*, *Meekella striato-costata*, *Strophalosia subquadratus*, *Derbya crassa*, *Meekella* (?) *shumardiana*, *Spirifera planoconvexa*, *Chaetetes* sp.	15	874	
			Florence flint; a massive limestone with prominent layers of flint.	*Productus semireticulatus*, *Chonetes granulifera*. *Derbya multistriata*.	22	859	
			Yellowish chocolate and greenish shales.		31	837	
			Light gray limestone with a fauna of small *Lamellibranchia*.	*Pleurophorus subcuneatus*, *Bakevellia parva*, *Edmondia calhouni* (?).	2±	806	
			Shales.		12±	804	
			Shaly buff limestone containing large *Brachiopods*.	*Derbya multistriata*, *Aviculopecten occidentalis*.	10±	792	
			Shales.		15±	782	
		Chase (Prosser).	*Strong flint*; two strata of light gray limestone containing an abundance of flint in layers, separated by a massive whitish limestone.	*Enteletes hemiplicatus*, *Athyris subtilita*, *Chonetes granulifera*, *Meekella striato-costata*.	42	767	
		Neosho (Prosser).	Yellowish shales with *Brachiopod* fauna.	*Chonetes granulifera*, *Derbya crassa*, *Athyris subtilita*.	23	725	
			Massive gray limestone with *Pleurophorus*.		3+	702	
			Yellowish shales with thin shaly limestones.		36	699	
			Limestone with *Pseudomonotis*, at top and bottom, with shales between.	*Pseudomonotis Hawni*.	12	663	
			Green and chocolate-colored shales.		20	651	

TABLE SHOWING THE STRATIGRAPHIC POSITION, ETC.—*Concluded.*

Period.	Series.	Formation or stage.	Stratigraphic character of the different beds.	Characteristic fossils.	Thickness of beds.	Total thickness.	Thickness of formations.
Carboniferous.	Permian.	Neosho (Prosser).	Light gray shaly limestones containing *Pseudomonotis.*	*Productus nebrascensis, Pseudomonotis Hawni, Aviculopecten occidentalis, Pleurophorus subcostatus.*	4	631	
			Shales.		4	627	
			Dark gray silicious limestone, weathers to very rough surface.		2+	623	
			Yellowish shales with *Brachiopods.*	*Chonetes granulifera, Productus semireticulatus, Rhombopora lepidodendroides.*	6	621	
			Yellowish, blocky shales containing a *Lamellibranch* fauna.	*Pseudomonotis Hawni, Aviculopecten occidentalis, Meekella striato-costata.*	5	615	
		Neosho (Prosser.)	Greenish and chocolate shales.		11	610	
			Shaly limestones.		4	599	

We will now consider the more strongly characteristic limestones of the Permian formation. The Neosho formation has it in but little of special interest excepting the heavy shale beds which are cut here and there by thin but persistent limestones. The one at the base of the formation weathers rough, recalling the properties so characteristic of the "dry-bone" limestone.

THE LOWER FLINT BEDS.

First above the Neosho formation is an unusually heavy bed of limestone which is particularly characterized by the large amount of flint or chert that it carries. It might be stated in passing, however, that many of the limestones below this horizon are rich in flint; but the one now under consideration surpasses any and all of those below it in this respect. Along the Cottonwood river nearly one-third of its entire volume is flint; southward in the Flint Hills it carries an equally large proportion, and northward along the Kansas river perhaps as much as a fourth of the entire mass is flint. The limestone is heavily bedded and is so filled with fractures that it has no value for building purposes. At Strong City and other places it has been extensively crushed for railroad ballast, the frac-

ture seams in both the flint and limestone greatly facilitating the crushing.

The Lower Flint beds first appear along the Kansas river between Manhattan and Ogden, along the Cottonwood near Strong City and on the western slope of the Flint Hills farther to the south. They cover a zone of country extending from north to south entirely across the state. In thickness they are variable. Hay gives them in his Fort Riley section as 25 feet; Swallow gives them as 12 feet; and Meek and Hayden give them as 40 feet. On the Cottonwood river at the quarries near Strong City, at the top of the hill, they measure 26 feet, and probably had been considerably eroded. Southward in the Flint Hills district they have greatly increased in thickness. It is quite difficult to correlate these beds with those given in Gould's section of the Flint Hills, but approximately they correspond to the two heavy limestone beds of Gould which are 34 and 47 feet thick, respectively, showing the wonderful thickening in that direction.

THE UPPER FLINT BEDS OF HAY, OR FLORENCE FLINT OF PROSSER.

Ascending from the Lower Flint beds through about 65 feet of alternating shales and thin limestones, along the Kansas river, and 112 feet along the Cottonwood, according to Prosser, and fully as far in the Flint Hills area, we find another heavy limestone formation carrying excessive amounts of flint. Along the Kansas river, according to Hay's Fort Riley section, but one limestone occurs in this interval; according to Swallow two or more are present; while Meek and Hayden give but one. Along the Cottonwood river two or more thin limestone beds are observed, and in the Flint Hills district five or six appear.

These Upper Flint beds are about 40 feet thick along the Kansas river, and increase southward to fully 75 feet in the Flint Hills area. They occur east of Fort Riley, from which point they are very prominent southward, passing by way of Florence where they have been extensively quarried for ballast, and constitute the rocks on top of the hills along the eastern crest of the Flint Hills. They are fully as prominent throughout the zone crossing the entire state from north to south as the lower flint beds are, as already described.

THE FORT RILEY, OR FLORENCE LIMESTONE.

Along the Kansas river, immediately above the Upper Flint beds, we find a 15-foot bed of shale, according to Hay, but one of only 5 or 6 feet thick according to Swallow, and Meek and Hayden. Along the Cottonwood river the shale bed is not to exceed 15 feet, and probably less. Southward in the Flint Hills it is possibly not quite so thick. This shale bed is of relatively little importance. Above it lies a prominent limestone from 6 to 10 feet thick which Hay calls the main Fort Riley ledge. It extends southward to the Flint Hills area, is prominent in the stone quarries at Florence and at intermediate points. It can be plainly seen along the line of bluffs in the vicinity of Fort Riley and many other parts of the state. Above it for a distance of 30 or 40 feet we have principally limestones with thin shale partings irregular in thickness, so that the whole mass taken together forms one extensive limestone deposit. In places these beds carry considerable flint, but not nearly to so great a degree as do limestones of the Lower and Upper Flint beds already described. Above this mass of limestone and shale we have 50 or 60 feet of shale, then another 4-foot limestone, which carries so much flint that Prosser has named it the Marion Flint.

Aside from the palaeontologic importance of the beds above these there is nothing about them which specially attracts attention. In the upper portions the limestones are so few and the formations so thin that one is reminded strongly of the uppermost parts of the Coal Measures. Here and there gypsum is found occupying a place within the shale beds, in some instances to a very considerable extent. The uppermost portions of the Permian in the central part of the state grade into a mass of red clay shales of somewhat doubtful significance. Cragin* has described them under the new name of "Mentor beds." Along the southern part of the state over a considerable area, reaching from near the Arkansas river westward to Meade county, the so-called "red beds" cover the surface. It has generally been supposed they pass under the Tertiary and Dakota formations to the west and north. Recently Kirk† has found that the well records obtained from various borings throughout the salt-

* Cragin: Am. Geol., vol. —, p. —; Minneapolis, September, 1895.

† Kirk: Unpublished manuscript, now in preparation, on the Salt Beds of Kansas.

producing area extending from the south line of the state to as far north as Kanopolis, show that the "Red beds" reach northward in what seems to be unbroken extent throughout this whole distance. Dr. Sharpe also found during the summer of 1895 from as far south as the middle of Marion county to beyond the Smoky Hill river a bed of clay shales, principally red in color, occupying a position between the uppermost Permian limestone and the massive brown Dakota sandstone. There is a possibility, therefore, that the "Red beds" so extensively developed along the southern part of the state pass northward under the Dakota sandstones to beyond the Smoky Hill river and constitute the beds described as "mentor beds" by Cragin. Investigations which are now being made by Kirk, it is hoped, will determine the matter.

The exact correlation of these "red beds" is somewhat a question of doubt. They have been called Permian by some, and Jura-Trias by others. This question will have to be settled ultimately by palaeontologic evidence, and as this Report is purely stratigraphic, making no pretension to palaeontologic discussions, no attempt will be made to decide such a mooted question.

It is also interesting to know that the salt beds so extensively developed in Kansas belong to the upper portion of the Permian. The recent investigations of Kirk have shown this so plainly that it seems there can be no doubt in the case. Well records have been obtained from many different parts of the salt region which, when drawn to scale and compared, show very conclusively that the salt beds lie above the heavy limestone beds, and below a bed of blue shale which in turn is below the "Red beds." As the blue shales so well developed in Sumner county and adjacent territory underlie the "Red beds," and as the latter are admitted to be the first above the Permian, it follows that the blue shales are Permian. But as the salt beds are below the blue shales, which approximate 300 feet in thickness, they are well within the Permian.

RATIO OF THE PERMIAN LIMESTONES TO SHALES.

It seems that the proportion of limestones in the Permian is smaller in the northern part of the state and gradually grows larger until the Flint Hills area is reached, where more than half of

the distance occupied by Gould's section is limestone. The general section given by Prosser is about 280 feet limestone and 515 feet of shale, or about one-third of the whole thickness is composed of limestone.

INCLINATION OF THE STRATA IN THE PERMIAN.

Throughout the whole of the Permian formations the general inclination of the strata is to the west. On account of the excessive thickening in the Flint Hills area the maximum dip doubtless is to the northwest. This has been remarked by almost every geologist who has visited the country. In some instances over miles of extent the inclination reaches from 14 to 16 feet to the mile, but probably the average for the whole formations in the state is but little more than 10 to 12 feet. It is not known how far westward the inclination continues in this direction. The "Red beds" which immediately overlie the Permian are known to dip to the west as far as Great Bend, while the Cretaceous and Tertiary formations in the western part of the state are inclined to the east and northeast; but just where the division line is located between these two directions of inclination has not yet been determined.

FAULTS IN THE PERMIAN.

Faults are almost unknown in this formation, yet in the Permian rocks about a mile east of Chapman along the Smoky Hill river it seems that a double fault has been produced. Two limestone beds, the upper one 8 feet thick, the lower one 2 and separated by 6 feet of shale, have been broken and depressed, producing a wedge shaped fault, the vertical displacement being about 3 or 4 feet. This has been described by Adams in the latter part of chapter VI.

GENERAL RESUME.

In summing up the general conditions for the whole Carboniferous of the state above the Mississippian we find that the beds will aggregate about 3,545 feet in thickness, which may be divided as follows:

Lower Coal Measures	800 ft.
Upper Coal Measures	1,950 ft.
Permian	795 ft.

Of this we have a grand total of about 820 feet of limestone and 2,725 feet of shales and sandstone, or a ratio of limestone to the whole thickness of 1:4.3. It should be clearly understood that perhaps no one point could be found under which the actual thickness of the whole Carboniferous would be quite as great as the figures above given. But, on the other hand, there can be no question but that this estimate is decidedly below the aggregate obtained by using the maximum thickness for the various formations as they occur in the state. Correspondingly by counting portions of the formations at one place and other portions at another we could make their thickness either greater or smaller than the figures above given. It may well be assumed, however, that on the highest hill-tops a drill would have to penetrate about 3,500 feet to pass out of the Coal Measures.

CORRELATIONS WITH THE WORK OF OTHER GEOLOGISTS.

So far as the writer has learned, Swallow is the only geologist who has ever undertaken the construction of a complete section of the Kansas Carboniferous, and his work was of an elementary character.* Meek and Hayden† constructed a geological section along the Smoky Hill river from the Cretaceous down to the upper portions of the Upper Coal Measures, but did not at all attempt a complete geological column of the whole area. Since that date Mudge, St. John, Broadhead, Hay and others have added greatly to our knowledge of Kansas geology by publishing papers from time to time on the different phases of the geology of the state, the most of which have already been referred to in the earlier chapters of this Report.

The geological section constructed by Swallow was a great help in its day to the study of Kansas geology, but when a close comparison is made between it and the conditions as they are actually observed it is found that in many instances his correlations are greatly in error. For example, his Cave limestone, number 156, is given as occurring on Sugar creek and at Topeka; his Spring rock, number

* Swallow: Prel. Rep. Geol. Surv. of Kas.; Lawrence, 1866.

† Geol. Expl. in Kas. Ter., by F. B. Meek and F. V. Hayden; Proc. Acad. Nat. Sci., Philadelphia, pp. 8-30, 1859.

162, is mentioned as occurring on the Marais des Cygnes, west of Topeka, and at Lecompton, and being below the coal, number 160, which occurs in Miami county; and still lower down, number 164, bituminous coal is given as occurring at the old Baptist Mission west of Topeka, while the blue shales, number 166, are mentioned as occurring west of the Baptist Mission and at Lecompton. Now, the facts are that the highest formations in Miami county, and therefore the coal, number 160, are several hundred feet below anything which may occur west of Topeka, while all of the materials about the old Baptist Mission and at other places west of Topeka are equally several hundred feet above Sugar creek and other localities mentioned, while Lecompton occupies an intermediate position not less than 200 feet from either of the other two localities, the one above it and the other below it. Again, his bituminous coal, number 176, occurring west of Lawrence, is placed about 120 feet below the Well rock, number 16?, yet quite probably his Well rock corresponds to the Garnett limestone, and if so, instead of being 120 feet above the thin seam of coal west of Lawrence it should be about as many feet below. Passing on down to his number 184, a limestone is mentioned as occurring at Lawrence, although by his own figures it is 425 feet below the Well rock, or Garnett limestone, which in turn is fully a hundred feet below the river valley at Lawrence, making a vertical error of not less than 525 feet in this instance.

These discrepancies are mentioned, not to discredit the work of Swallow, for it was a great and good work and laid the foundations upon which nearly all of the subsequent geological investigations of the state have been conducted. They are mentioned merely to show why it has been found impossible for the present Survey to follow his section very closely regarding names and geographical localities.

CHAPTER X.

PHYSIOGRAPHIC FEATURES OF THE CARBONIFEROUS.

BY ERASMUS HAWORTH.

The discussion of the physiographic features of the Carboniferous area has been delayed until after the general stratigraphy was given, contrary to the usual custom in geological reports, in order that the geology might be used to explain the physiography, which, for this area, seems more desirable than to use the physiography to explain the geologic structure. The workers in the field, however, early learned the relation between the two, and therefore constantly made use of whatever class of information they possessed for a given area to help them in the investigation of the other. Physiography was often used in determining stratigraphy. Many an escarpment was viewed miles in the distance and the facts in its location used to determine points in stratigraphy. The greater the escarpment the heavier the shale beds were supposed to be, and in many other ways physiography was used to advantage while in the field. Also, known facts in stratigraphy have been used in the study of the physiography; for, as the reader has already observed from the contents of the preceding chapters, each person while in the field made a careful study of the physiographic features of the area passed over.

ELEMENTARY CONSIDERATIONS.

Before taking up the detailed description of the physiographic conditions it may be well to give a hurried review of such general principles in land sculpture as may be immediately applicable. Let us first consider the method by which a river reaches its base level* when passing through slightly inclined alternating strata of relatively thick, soft material, such as shales, and thin, hard material, such as limestones, when the inclination of the surface is opposite in direction to the inclination of the strata. Figure 9 will assist in this discussion. Let the original surface be A, A^1, with the strata dipping to the left and the river flowing to the right. The first effect

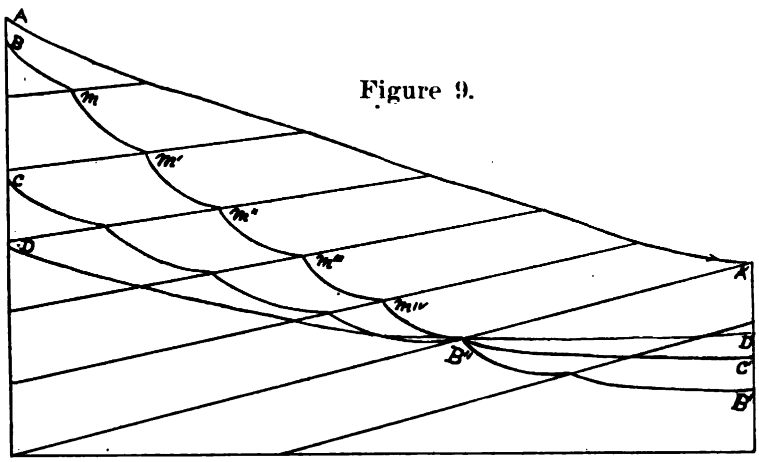

Figure 9.

Diagram showing the erosion of rivers, longitudial section.

of the comparatively rapid current will be to wear away the soft material more rapidly than the hard, producing greater or lesser cataracts and falls at the points m, m^1, m^{11}, etc. But as the corrasive power of the stream will increase with the volume of water the work will be more rapid towards the mouth and will cut its channel through the distance A^1, B^1, while nearer the source it has only worn through the distance A, B. During the process the principal corrasion produced by the water will have taken place on the softer materials and the harder rock will be worn away principally by frag-

*This term was first introduced by Powell in his Report of the Explorations of the Colorado River, 1875, p. 203, and has since come into general use.

ments, large or small, dependent upon the frequency of seams within the rock, falling after they have been undermined. In the course of time the stream will have worn its channel to a depth, B^1, beyond which it cannot go because it is now so nearly at sea level that the velocity has been so checked that further corrasion is impossible. Vertical corrasion will, therefore, cease at that point. Farther towards the source, however, the inclination is substantially the same as at the beginning, and the velocity will be sufficient to greatly corrade the channel and to provide the stream with large quantities of detrital material. In this way the channel will be worn deeper to the left, until the condition of base level will gradually have receded, we will say, to the point B^{11}. Base level will, therefore, first be reached near the mouth of the stream but will gradually recede up stream as corrasion is continued until finally, should no other changes be introduced, the base level will have been reached throughout the whole length of the stream. It has been shown by Taylor and others that the form of the corrasion curve B, B^{11}, B^1, under ordinary conditions approaches a parabola.

As soon as base level is reached at B^1 the velocity will be checked to a sufficient extent to cause the current to unload a portion of the material it is carrying, and a filling-up process will begin, so that by the time base level has receded to B^{11} the filling near the mouth of the stream will have reached perhaps to C^1. But with the erosion of the general land area the continental portions will be worn down until the source of the stream will have a decreased altitude. This of itself would tend to decrease the velocity of the stream. By and by when the continental level has been reduced from B to C and from C to D, the checking of the current would have caused sufficient deposition near the mouth of the stream and along the lower part of its course to have filled the valley with loose material to a height of B^1, the same valley which earlier in the life history of the stream was produced by corrasion of the current. The various cataracts and falls, m, m^1, m^{11}, etc., will gradually disappear as these conditions are brought about, partly by a change in the method of erosion and partly by the filling up of the gorges which have been worn out in the softer material just below the harder.

If we consider the condition at any one time as the velocity is

being checked it will be seen that the first material to be unloaded by the current would be gravels and the coarser sands. Later when base leveling had receded farther up stream a finer grade of sand would be deposited over the coarser gravel and this in turn by finer and finer material, until at the top of the filling the finest silt would be found. Therefore if the material which has been deposited by the river should be dug into at any point it would reveal a mass of coarse gravel at the base, no matter where along the length of the stream the examination was made. Many noted streams in different parts of the world are good examples of this condition. The amount of filling, the distance D^1, B^1, that will be produced along the lower parts of the stream will depend on many conditions. If the stream is a long one and its source greatly elevated, and should it pass over large areas of loose material, as the sands of the great plains, vast quantities of sediment will be borne downwards which can never reach the ocean on account of the checking of the velocity of the current, and which must, therefore, be dropped throughout the lower part of the valleys. But if the course is short and the source not greatly elevated and the materials over which the stream flows difficult to erode, the filling process below will not reach any considerable proportion. The Missouri river rising in the great mountainous district thousands of feet above sea level and flowing over the loose sandy plains has a strong velocity and readily becomes loaded with large quantites of sand and silt. As it progresses oceanward, however, the inclination of its channel is decreased until long before the Gulf of Mexico is reached its velocity has become so checked that it is compelled to deposit large quantities of the material which farther to the west it carried with relative ease. Other tributaries of the Mississippi and many other streams in America and elsewhere illustrate this principle on a grand scale.

With but few exceptions our streams in eastern Kansas have all reached the condition of base level, or the stage represented by D, D^1, so that throughout the lower part of their course a filling-in process has been carried to considerable extent. This is particularly true of the Kansas river, the Osage river, the Marmaton river, the Neosho river, and the Verdigris river. At Lawrence the water company

has made numerous borings in the river valley and has found that certain limestones and sandstones existing along the banks have been worn away and that the depth of the river valley at one time was 50 or 60 feet greater than it now is. The gravels in the lower portions of the filling are much coarser than those above, just as would be expected. In the coal mining operations at Boicourt it was found that the filling of the Osage valley had reached as great a thickness as that noted above at Lawrence, and with coarse gravel at the bottom. But below the silt and sand and gravel the regular stratified rocks were found. Borings at different places along the Neosho, particularly at Burlington, where a water-supply was sought, have revealed a similar condition. The old river channel has been filled in first with coarse gravel, then with finer, and finally with ordinary silt and soil on top.

Figure 10.

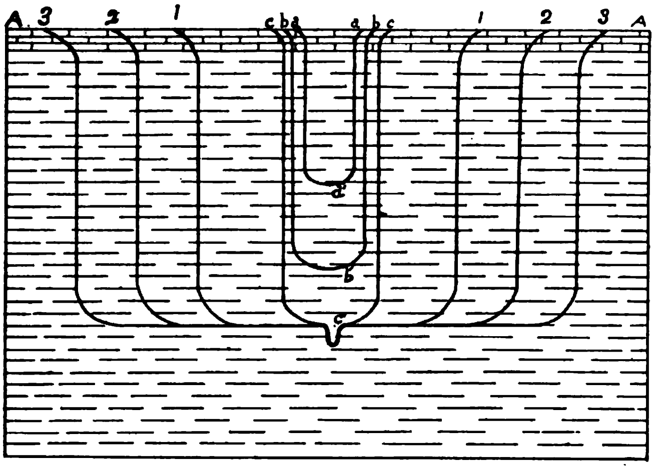

Diagram showing the erosion of rivers, cross section.

It is usually understood by the masses of the people that this filling-in process implies a lowering of the general level of the country where the filling has taken place. But it will be seen that such is not necessarily correct, as a filling of some kind is a necessary result and has occurred or must occur in the life history of every stream. Should there be produced a slight decrease in the altitude

it will intensify the filling operation and in many cases where the increase of filling has been but little it will be difficult to recognize.

Let us now turn our attention to a study of the cross section of a stream which is flowing over materials similar to those assumed in the previous discussion. Prior to the time when base level was reached at this particular point the vertical corrasion of the stream would be so rapid relatively that the lateral corrasion need hardly be considered. Let us suppose the channel worn to a depth represented by a, a^1, a, figure 10, at the beginning of our consideration. Shortly after it would have reached a condition represented by b, b^1, b. The downward course would progress rapidly until base level was almost or entirely reached, when a condition similar to c, c^1, c would be obtained. But now the vertical corrasion will cease and the slow but continuous process of widening the channel will become apparent. Let us now assume that the surface A, A^1 is covered with a hard formation such as limestone, while the remainder of the materials represented are soft and friable shales. The widening of the channel will be produced principally by local rains, during which time the multitudes of little rivulets will carry materials into the river. If the hard layer did not occur at A, A^1 the bluffs would assume rounded outlines, and the upper portions of them would recede laterally from the river much more rapidly than the lower. But the durable limestone covering at A, A^1 prevents this. It will be worn away principally by being undermined so that block after block of it will fall below. In this way the walls of the bluff will be kept very steep if not almost precipitous.

Lateral erosion is slow. The bluffs are worn away mechanically by the rains in times of freshets, and chemically by the percolating waters dissolving materials, so that every little spring, or even the surface rivulets which flow from the hillsides are constantly carrying away portions of the bluffs. But in geology time is long. The widening process will continue until the valleys of one stream coincide with those of its neighbors. During all this time the upper surface of the valley, B, B^1, would maintain about the same level, provided general orographic movements do not interfere, excepting as the flood plain is gradually filled in with silt in times of overflow. Different Kansas streams have in this way produced valleys

from three to five miles wide. It will be seen from this consideration that after a stream has reached its base level the quantity of water which it carries is of little importance in widening the valley. It is the amount of rainfall in any particular location, and the rapidity of corrasion produced by that rainfall, and the amount of materials carried away in solution by the percolating waters which determine the rate of widening. All that is required of the stream is that it carry away this local drainage.

But the lateral tributaries must also reach base level as well as the stream itself. The widening of their valleys will therefore progress about as rapidly as the widening of the valley of the larger stream. This is illustrated in hundreds of places in Kansas. The valley of the Wakarusa south of Lawrence is as wide as that of the Kansas river to the north, while some of the little tributaries to the Wakarusa not more than six miles long have valleys half as wide. The greater the number of lateral tributaries the more rapidly the general erosion of a district will be produced, for they so greatly increase the surface exposed to erosion. A tributary six miles long will have twelve miles of bluff. If its valley is three miles wide it has increased the bluff surface to fifteen miles, instead of the three miles of bluff were the tributary not existing, and the rapidity of the general erosion has been correspondingly increased.

The immediate river channel in all these wide valleys is from 10 to 30 feet below the surface of the valley land, and frequently the walls of the channel are almost perpendicular, as is shown in figure 10 at c. The existence of this particular channel is principally due to the solvent action of the water on the earth immediately in contact with it.

After a stream has reached its base level it usually begins a process of meandering from bluff to bluff, thus occupying much greater space than would be necessary could it follow the direction it had before base level was reached. This condition is particularly well represented in the Kansas river and the Osage river near the eastern part of the state, and is less perfectly represented by the Neosho and Verdigris rivers throughout their course.

One other condition should be mentioned before passing. Let us suppose a river has reached its base level throughout a large part of

its course, and has assumed a meandering direction. Later let there be a general elevation of several hundred feet throughout the course of the stream. This would increase the fall, and consequently the velocity, so that vertical corrasion would be renewed. Ultimately the stream would again reach its base level, and then the widening process would produce a new valley. We would therefore have two sets of bluffs, the one below the other, or a terraced condition, the intensity of which would depend on the abruptness and the height of each individual bluff. Such a terraced condition is usually considered good evidence of one or more periods of orographic movement since the stream first reached its base level. There is to-day a new physiography, or new physical geography, based largely on the interpretation of such conditions; for it will be seen that our river valleys and river bluffs have recorded in them the life history of rivers, and records of oscillations of surfaces since the streams came into existence, or since the continents were formed.

Figure 11.

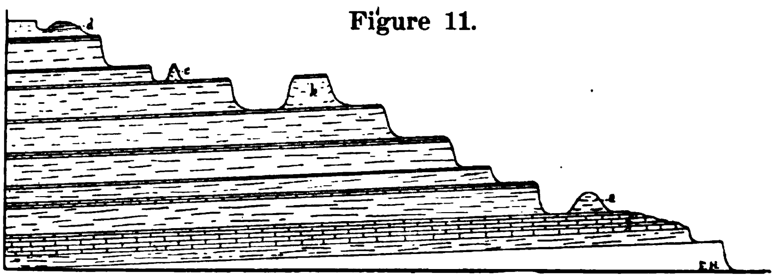

Diagram showing the nature of the general surface erosion. (Kansas Univ. Quar., vol. 2, p. 132.)

Having thus considered the general results produced by river erosion of materials similar to those composing the Kansas Carboniferous we may now extend the principles to the whole surface of the country. Figure 11 is a diagrammatic and condensed representation of the surface of eastern Kansas, together with the peculiar properties of the rocky crust of the earth upon which the contours depend. It represents a series of limestone systems approximately parallel dipping gently to the west and outcropping on a surface inclined towards the east. The intervening spaces are filled with shale or other matter which readily yields to erosion. The right hand

limit of each limestone system therefore is marked by a terrace nearly as high as the distance downward to the next limestone; for, as already seen, the friable shale will yield rapidly and almost or entirely undermine the limestone mantle above, which in time will break away as it is undermined, thus allowing the terrace to recede westward.

Often the limestones will have been fissured back of the terrace, as shown at b and c, so that a valley has been cut between it and the main land, leaving a flat-topped mound standing alone. Such mounds are of most frequent occurrence, and give a picturesqueness to the scenery which cannot be described. The frequency of such geographic names as Mound City, Mound Valley, Twin Mound, Blue Mound, etc., tells its own story.

The walls of such mounds will always be steep, and sometimes almost precipitous, but their formation is easily understood, and is the same as that just given for river bluffs. Thus, the diameter of the top of mound b, figure 11, remains constant for a long period on account of the protecting influences of the rock at the summit. But the basal diameter is rapidly growing shorter, because the shale composing the mound so readily yields. Should one or more of the limestone systems have an outcropping many miles in length an escarpment would mark the outcropping throughout, the wall of which would correspond in shape and abruptness to the face of the mound.

THE KANSAS RIVER.

We will now enumerate the more important rivers which flow partially or wholly across the Carboniferous area, give their principal physiographic properties and discuss such other questions regarding them as may seem pertinent. The largest stream in the state is the Kansas river which is formed by the confluence of many tributaries, the most important of which rise in the extreme western part of the state, or just across the line in Colorado. Its valley is cut down through the various formations, so that the uppermost members of the Carboniferous are reached a little west of Abilene. The Permian rocks constitute the main mass of the bluffs from Abilene to Manhattan. From here to its mouth the river flows entirely

through the Coal Measures. The bluffs just west of Abilene are low relatively, and gradually receding, and are composed principally of the Dakota sandstones, which have but little variation of hardness throughout their mass. Below this both the Permian and Coal Measure formations are composed of alterations of limestone and shale, producing steep bluffs, which in extreme cases reach 300 feet in height.

A careful examination shows that the height of the river bluffs is quite irregular. Occasionally they come down to within 50 or 75 feet of the river, but either east or west rise again to much greater heights. Wherever such a low height is reached it can be readily seen that the limestone which dips to the west is here lower than it is farther east, and that the first one above is well worn away at this particular place, but is found farther west capping higher bluffs. Topeka, Lawrence, and Eudora, each is a good illustration of this. At Topeka the uppermost limestone to the east has dipped until it is only about 75 feet above the river. The first limestone above has been worn away for a few miles farther back, but westward we soon reach the bluff protected by it, while to the east the surface rises with thė limestone which is on the surface at Topeka. At Lawrence the Oread limestone extends eastward just to the west city limits. The Lawrence shales have been cut into about 200 feet, but there is practically no bluff on the south bank, as the Wakarusa valley joins the Kansas river valley here. A few miles below Lawrence the south bluffs begin rising, having for their protection the thin limestone shown in plates VI and VII as occurring about 150 feet below the Oread. By the time Eudora is reached in our journey eastward the Eudora-Garnett limestone has come to the surface, so that it forms a protection to the bluffs on both sides of the river. They are here less than 100 feet high, but gradually rise to the east on account of the limestone continuously assuming higher positions. This is easily recognized by any one passing between Lawrence and Kansas City on either side of the river. The Eudora limestone may be traced all the way to Argentine, at which place it occupies a position about 250 feet above the river, with the bluffs correspondingly increased in height.

Disregarding, therefore, the channels cut by the lateral tributa-

ries, we may describe the bluffs of the Kansas river from Kansas City to Manhattan as representing in profile a series of great steps, the floor of each one of which gradually dips to the west until it reaches a position much nearer the water level than it occupies farther east. The risers in this great stairway are the greater and lesser escarpments facing eastward which mark the eastern outcroppings of the successive limestone systems. Westward from Topeka a few miles, as shown in plate VI, the limestone systems become thin and moderately close together. There the vertical erosion of the river has exceeded the general areal erosion of the country, so that a larger number of limestone systems are worn through by the river without being removed from the surface of the country. Bluffs in this locality are high and much more retreating than farther below. But the river valley maintains its width so that the bluff lines are well marked, and their faces are composed of numerous little terraces each one of which is produced by the existence of one of the thinner limestone systems. Buffalo Mound, a short distance to the south from the river, in this way rises to a height of 300 feet or more above the river valley.

Only a few places can be observed in the river channel from Abilene to Kansas City where the limestone ledges are visible, in all the other instances the filling-in process having entirely covered them up. There may be no doubt, however, but that in the youthful period of the stream many cataracts and falls, some of them hundreds of feet in extent, lined the river from its mouth to at least as far west as the western limits of the Carboniferous. The great Lawrence shale bed nearly 300 feet thick would yield so readily to erosion that we may safely conclude the Oread limestones and the Lawrence shales caused cataracts and falls which rivaled in height and grandeur the Niagara Falls as we now see them. The high bluffs at Kansas City likewise, composed as they are of such heavy beds of limestone with great shale beds beneath, probably produced similar falls in the Missouri river at or below Kansas City. Other places could be named, but these are the most striking. In fact some of the lesser tributaries of the Missouri and Kansas rivers have such falls still in existence although they are rapidly passing away.

TRIBUTARIES OF THE KANSAS RIVER.

The Kansas river has numerous tributaries entering it from both sides. On the north Blue river enters it at Manhattan. It has cut its channel through the various systems of limestone and shale, so that its bluffs are as high and as precipitous as those of the Kansas river. The valley also is nearly as wide, but gradually grows narrower towards its source. Below Manhattan Mill creek enters the Kansas river from the south. It rises away to the southwest in the uppermost parts of the Permian. It has cut its valley through the various heavy limestone systems to about 100 feet below the Cottonwood Falls limestone. Throughout the most of its course its valley is relatively narrow, but its bluffs are similar in every respect to those of the Kansas river. At McFarland its south bluff is almost precipitous, rising to a height of 200 feet. The north bluff, however, is very receding, consisting of a gradual slope rather than a bluff proper. This condition is largely due to the particular character of the rocks which favors such a slope. Below this the next important tributary is the Delaware river, which enters from the north. It rises on the high divide separating the Kansas river from the Missouri. It has cut its channel into the surface to so great a depth that its bluffs in many places are as high as any known along the Kansas river. Its bluffs are remarkable for their precipitous character. Its valley is not as wide as the valley of the Kansas river, but in places towards its mouth it almost approaches such a width. This stream has not reached base level throughout the whole of its course, for in different places the water plunges over greater or lesser falls caused by the resistance to corrasion offered by limestone strata. The name, Valley Falls, of a town located on its bank implies this.

From the south the Wakarusa enters the river near Eudora. Its course is but little more than thirty miles in length and lies nearly parallel to the Kansas river, so that the drainage area between the two is narrow. The Wakarusa has cut its channel to a depth equalling that of the river, and throughout more than half its length the valley is approximately as wide as the Kansas river valley. On account of the sharp angle it makes with the river the upland be-

tween the two valleys has been worn away farther to the west than we find for the other tributaries. Lawrence is situated at the extreme southeast extent of the highlands between the two valleys. Just east of the city the valley from the north bluffs of the Kansas river extends southward to the south bluffs of the Wakarusa, a distance of fully fifteen miles.

Other smaller tributaries enter the river in many places, and also the various tributaries mentioned have their own lateral tributaries. The whole of these seem to have practically reached their base level. Those entering the Kansas river cannot deepen their channels until the river is in some way reduced to a lower level, while the greater portion of the smaller tributaries likewise have already cut their own channels almost as deep as will be possible. Many of the smaller streams have also widened their channels until in numerous instances a stream not more than ten or twelve miles long has a valley towards its mouth three or more miles wide. This is well illustrated by the little branch which enters the Wakarusa from the south, along which the Atchison, Topeka & Santa Fe railroad passes from Lawrence to Ottawa.

ABSENCE OF COMPOSITE TOPOGRAPHY ALONG THE KANSAS RIVER.

Careful examination was made along the bluffs of the Kansas river and its various tributaries for indications of composite topographic features which would have resulted had there been any very considerable uplifting of the country in the environs of the source of the river after it had first reached its base level throughout the lower portions of its course. As was explained in the earlier pages of this chapter, when a stream reaches its base level and has widened its valleys a subsequent elevation of the drainage area will cause a second deepening of the channel, and a corresponding widening of its new valley after base level is reached a second time, which will result in the production of a terraced condition of bluffs. The meanderings of the stream during the period of the widening of its first valley would also be indicated in the more or less tortuous course of the second bluff line. If, therefore, such stages have been passed through by the Kansas river, we should find their history recorded in the character of the bluffs. Not a single instance is observable

of a distinct approach toward a terraced condition in the bluffs of the Kansas river, or of any of its tributaries, excepting in the many instances where light terraces occur, each of which is plainly due to the existence of the hard limestone mass within the bluff. Such benches are always observable where there is more than one limestone system in the bluff. The width of the bench above the limestone rarely is more than fifty feet and usually but little more than twelve or fifteen, so that they could not be represented on a topographic map of ordinary character. This matter is one of great importance in connection with the geologic history of Kansas. Throughout the three seasons of field-work its importance was constantly in mind and observations as continuously made with an earnest hope to discover such terraced conditions should any exist. A general consideration of the bluff lines themselves also indicates an absence of composite topography. An examination of the topographic sheets issued by the United States Geologic Survey shows that the bluff lines of both river and tributaries are remarkably regular, there being no approach whatever to the sinuous directions the secondary bluffs would have assumed had they been outlined by the sinuous course the river assumed after it reached its first base level. This indicates that it will not do to assume that in past time the first set of bluffs produced has been entirely removed by the erosion.

LIFE HISTORY OF THE KANSAS RIVER.

Both Professors Williston and Hay, as well as others, have shown that the principal tributaries of the Kansas river existed previous to Tertiary time, that they had worn great channels in the upper members of the Cretaceous rocks, and that subsequent to Tertiary time the channels assumed by the present tributaries correspond very closely with those occupied during pre-Tertiary time. Throughout the Carboniferous* area there is no indication whatever of a change of location of any considerable extent having occurred anywhere in the course of the river or of any of its principal tributaries. We may therefore conclude that its present location is substantially

* Doctor Sharp, of McPherson, has probably found an old river channel at McPherson in the Dakota, an account of which will be published soon.

the same it has occupied during all of its existence since the general western uplift at the close of the Cretaceous time.

The question naturally arises regarding the cause of the location of the river along the particular course where it is now found. This can be only partially answered. As has been shown in the preceding chapters, the great persistency of limestone strata throughout the Coal Measures is accompanied by many gentle variations in dip, so that we have anticlinal ridges and synclinal troughs some of which extend over relatively large areas. The rocks on the south side of the Kansas river dip towards the north. At Lawrence there was previously a light dip towards the south throughout portions of the river valley, as is abundantly shown by the fact that the Oread limestones on the bluffs north of the river are a little higher than they are on the south. This can only be accounted for by the previous existence of a synclinal trough which possibly helped determine the primitive drainage channel. Also just above Kansas City we have a similar condition, rocks dipping northward on the south bank, and yet occupying slightly higher elevations on the north. These variations are slight, but wherever observed throughout the course of the river, they indicate that in its earliest stages the river channel was located along the synclinal troughs.

THE OSAGE RIVER.

This stream rises in the vicinity of Burlingame and passes out of the state almost oppposite Pleasanton. From Ottawa eastward it has a wide valley, and, in many places, high and irregular bluffs. The general character of the topographic features are practically the same as those described for the Kansas river. The bluffs are either low or high according to the present location of the protective limestone systems. In the vicinity of La Cygne and Boicourt where the Pleasanton shales are so heavy, with the numerous limestone systems close together above them, deep and wide valleys for the river and its tributaries result, while farther up stream, as the same limestone systems reach lower levels, on account of their westward dip, the bluffs correspondingly decrease in height. This has occurred to the greatest extreme in the vicinity of Ottawa, where the

bluffs are little more than 50 feet high. A few miles to the west, however, the outcropping of the Oread limestone is met, and the bluffs correspondingly amount to nearly 200 feet. The widening of the channel of the Osage has not progressed to nearly so great an extent throughout the principal portions of its course as it has farther below. At La Cygne the valley is about four miles wide, with the river meandering from bluff to bluff in an exceedingly tortuous manner. At Boicourt Sugar creek valley unites with the Osage river valley, so that we have a condition similar to that already described at Lawrence where the Wakarusa valley unites with the valley of the Kansas river. But here the underlying limestone rises to the south very slowly, so that as one passes along the line of the Memphis railroad one seems to be in this low valley for twelve or fifteen miles. Here also it may be noticed that the Sugar creek valley is as wide as that of the river itself. This has plainly been brought about by erosion, the Osage river having long ago reached its base level to a point above the mouth of Sugar creek.

ABSENCE OF COMPOSITE TOPOGRAPHY.

An examination of the bluffs of the Osage and its tributaries was no more productive of indications of composite topography than has already been described for the Kansas river. Look where we will such features cannot be found. The bluffs in places have miniature terraces, but such terraces plainly are dependent upon the protective influence of local limestone systems. An examination of the topographic sheets also reveals a moderately straight and even direction for the bluff lines, at least an absence of the degree of sinuosity one would expect to find were the bluffs previously outlined by the meanderings of a stream which had reached its base level.

If we now look for an explanation for the Osage river being located in the particular position it occupies, we find causes about as efficient as those mentioned for the Kansas river. As is shown in plate II, the limestone systems which cover the hills at Boicourt dip rapidly to the north to the bluffs at La Cygne, while beyond they rise to Fontana. This is one of the greatest synclinal valleys known in the state, and the Osage river at this place occupies the synclinal trough. It is true it has worn through the limestones, but in its

earlier stage quite probably had its position determined by the limits of the synclinal producing a natural valley through which it flowed. Farther up stream nothing of the kind has been observed, but if the location was determined for the lower portions the upper parts would naturally have assumed the positions near where they are now found.

THE POTTAWATOMIE RIVER.

This stream is short but has a very interesting topography. It rises on the surface of the Garnett limestone to the west of Garnett. Its tributaries have cut through this limestone, and have eroded deep valleys into the underlying Lane shales. Its bluff lines are almost straight, its valley is relatively wide throughout most of its course, and its bluffs correspondingly high. One feature of the valley particularly should be mentioned; from Lane to near Osawatomie the valley proper seems to rise toward the east. This at first sight seems rather remarkable, but on closer examination it was found that the Iola limestone covered the whole of this valley. The higher Garnett limestone of course was worn through by the stream before its vertical corrasion had carried it downwards to the Iola limestone horizon. The check in rapidity of vertical erosion due to the Iola limestone gave time for lateral erosion. In this way the widening process of the valley above the Iola limestone was far advanced before the river had cut through the latter. As one passes from Lane to Ottawa one will notice that the valley proper lies above the Iola limestone and is four or five miles wide, but the river has now cut through the latter limestone and the widening process of its second valley is in its incipiency, having reached a mile or more in the vicinity of Osawatomie. In this way there is an approach towards two bluff systems which might be mistaken for a change of level in the upper parts of the stream, causing it to reach a base level a second time. But the true explanation is that just given.

THE NEOSHO RIVER.

This stream rises in the central part of the state on the uppermost portions of the Permian as it is now exposed. It flows in a general southeastern direction, making a gradual curve until it passes out of the state flowing almost south. The topographic features along

this stream are not so pronounced as those described for the Kansas and the Osage rivers, but they are equally interesting. Where its direction is approximately at right angles to the line of outcropping of the different formations the bluffs are about equal in height on either side. But as it changes its relative direction the south bluffs in places are less pronounced than the north. It would seem that this is due to the gradual rising towards the south of the different limestone formations, while towards the north the upturned edges of the same formations would be eroded in such a way as to produce more nearly vertical walls. Farther downwards, when the stream breaks through the line of outcropping of the Oswego limestone, the east bluff line which is in the Cherokee shales has melted away to a gentle slope receding four or five miles from the river, while on the west the protective influence of the Oswego limestone has caused a bluff to exist at Oswego which in places is almost vertical to a height of 150 feet. The general features, therefore, of the topography of the Neosho river are easily explained by the particular geologic conditions of the country over which it flows. The direction of the bluff lines is more curving than we have heretofore found for the other streams, but nowhere do they approach a sinuosity such as streams assume after they have reached their base level. On the contrary the curves are bold and gradual, implying that they are due to the general surface features which determine the directions the river should follow.

THE VERDIGRIS RIVER.

The Verdigris river rises in the Coal Measures proper not far from the southern limit of the Neosho drainage area. Its direction in the state is almost south. It has cut its channel through the Garnett limestone, the Iola limestone, and the Independence limestone, and has reached its base level almost to its source. From Benedict almost to Neodesha the Iola limestone serves as a protection for the bluffs on both sides of the river, while below this they cap the bluffs on the west to almost opposite Independence. The height of the bluffs throughout this distance gradually increases to the south; at Benedict they are about 75 feet high, while near Neodesha they are nearly 200. Below Neodesha the river reaches the Independence

limestone, and the Thayer shales permit the eastern bluff to recede from the river in a gentle manner similar to the eastern bluff of the Neosho at Oswego, while the Iola limestone causes the western bluff to be almost precipitous, but it has receded six miles or more from the river. Farther below, where the river has cut its channel through the Independence limestone, the bluffs protected by the Iola limestone gradually assume positions farther to the west of the river, so that at Independence they are four or five miles away. The elevation of the Independence limestone is but a little above the base level of the river at Independence, so that the river valley practically reaches to the surface of the Independence limestone, producing a sequence of conditions similar to those described for the Pottawatomie river valley between Lane and Osawatomie.

AREAL TOPOGRAPHY.

Having given in considerable detail the topographic features along the principal rivers of the state, we will now turn our attention to the general areal conditions of the high uplands between the various streams. Let us again refer to figure 11 which has already been explained. It approximately represents a cross-section of the general areal conditions. Here and there where ever there is a line of outcropping of an important limestone system there is a more or less pronounced escarpment facing the southeast. The vertical height of such escarpment is dependent almost wholly upon the thickness of the shales which underlie the limestone. Wherever two limestone systems approach each other vertically by thinning of the separating shale beds the two escarpments correspondingly diminish in boldness. This is well illustrated in the line of escarpment which reaches from La Cygne and Boicourt away to the southwest. As has already been pointed out in chapter IX, the walls of this escarpment vary in height from place to place as the thickness of the Pleasanton shales varies. Farther to the southwest the Erie limestone series is separated by the thickening of the intervening shale beds, and each one in turn has its own escarpment, as is so well marked in the vicinity of Mound Valley and Cherryvale. If one will pass across the country from the southeast towards the northwest one will be

continuously passing up a series of terraces similar to those represented in figure 11.

If the escarpment is bold and the underlying shale bed is thick, a series of mounds always exists to the southeast of the escarpment proper. These have plainly been produced by the erosive agents breaking through the protecting limestone farther to the west. Such mounds sometimes are large, with broad flat tops, as is so well illustrated by Table Mound described by Adams in chapter I; sometimes they are small like the frustums of cones, as is so beautifully illustrated by the mounds in the vicinity of Cherryvale and Mound Valley. In both these places the protective limestone is still maintained on the summit, as shown at b, figure 11. At other times the surface limestone has gradually been worn away until the mound consists entirely of masses of shale which may have a little sandstone interspersed. In these cases the summit of the mound will generally become rounded, as shown at a, or d, figure 11. Illustrations of this class are common throughout the country.

By referring to chapter IX it will be seen that above the Cherokee shales we have two particularly heavy shale beds, the Pleasanton shales and the Lawrence shales, and also that some other shale beds, such as the Thayer shales and Lane shales, in places assume considerable thickness. It is interesting to note how the great areas of mounds and escarpments coincide so exactly with the southeastern limits of these shale beds. Beginning at La Cygne and Boicourt, we have an area characterized by mounds and steep bluffs reaching to the southwest by way of Mound City, Uniontown, Cherryvale and Mound Valley to beyond the limits of the state. Above this we have the Thayer shales, which produce a similar topography in the vicinity of Neodesha and Independence. Passing upwards another similar condition is reached where the Lane shales come to the surface, so that from Osawatomie to the southwest by the way of Lane, Greeley, and Garnett, we have quite similar physiographic features. Then above this, where the Lawrence shales are most heavily developed, the same conditions are repeated. At Lawrence, Blue Mound stands off five or six miles to the east of the general outcropping of the Oread limestone with its protective cap of limestone nearly removed by erosion.

One cause which intensifies these physiographic features is the various tributaries of the principal streams cutting the channels through the overlying limestone. In this way a deep and wide valley with high bluffs may extend far into the interior beyond the limits of the river bluffs, and may repeat the features already described as characterizing the eastern faces of the great escarpments. A good illustration of this is found along Sugar creek, which rises to the southwest of Mound City. It has cut through all the overlying limestone a hundred feet or more into the Pleasanton shales throughout almost all of its course. Along the walls of its bluffs, therefore, we find mounds and promontories reaching out into the valley similar to those of the various general escarpments already described.

We find but few broad gentle rolling areas anywhere within the Carboniferous. The tributaries to the different streams have cut the whole country into valleys, and the residual portions which are not carried away by erosion constitute the hills, so that usually there is such a succession of hills and valleys that the whole country is not only well drained but moderately rugged. One can travel many miles in the direction of these ridges almost on a level, while perhaps in a transverse direction one or more deep valleys would be found every mile. The great Cherokee shale area in Cherokee and Crawford counties is an exception to this general rule. It is almost level throughout, there being a significant absence of any considerable hills or highlands within it, excepting in a few places where the Columbus sandstones have assumed considerable proportions, so that they serve as a protection for the underlying shales.

The general physiographic features of the Permian are similar to those of the Coal Measures. The river drainage valleys are as deep, and their bluffs as high as can be found anywhere in the Coal Measures. The only distinguishing feature that is readily apparent is the absence of the great escarpments over the general uplands, as have already been described for the eastern limits of the heavier shale beds below, such as the Pleasanton shales, the Thayer shales, the Lane shales, and the Lawrence shales. Throughout the Wabaunsee formation and the overlying Permian the absence of such heavy individual shale beds makes such great escarpments un-

known; but lesser ones are very frequent. In the vicinity of the great drainage valleys where the streams are cut so deep, passing many limestones in succession, the bluffs are usually most beautifully terraced, the horizontal distances between the terraces generally being small and the limitations very evidently being controlled by the limestone formations themselves.

THE FLINT HILLS.

Few localities can be found the physiographic conditions of which better illustrate the relations between stratigraphy and physiography than the Flint Hills area. Westward from Independence along the southern part of the state for some distance a sandstone area prevails. The Niotaze well, for example, passed 800 feet below the surface before limestone was reached. The limestone formations below this dip to the west until they are beneath the surface in this locality so far that they have not retarded erosion. From the vicinity of Independence westward, therefore, the whole surface of the country along the south line of the state has been composed of materials easily eroded, which accounts for the unusually low altitudes in the vicinity of the Verdigris river and to the west. But when the Flint Hills area is reached the heavy massive limestones, rendered more durable by the interbedded flints, resisted decay to such an extent that they have been affected only mildly by the corrasive agents. Westward from this area again we find an absence of hard materials; the strata dip rapidly to the west; many of them pass under the Arkansas river, leaving at the surface the soft, easily eroded sands and shales. It is therefore the most natural condition that the great Flint Hills area should now stand out prominently from the surrounding country to the east and the west, having been left behind while the adjoining materials were chiseled away, a result of the peculiar formations which exist throughout that area. The sides of the hills have as a consequence become very steep. This in turn has given greater corrasive power to the various little streams rising in the territory, which in turn have chiseled deep gulches on every side simulating in character and extent the gulches on the sides of more pretentious mountains. The very formations which have caused this peculiar physiographic condition

grow thinner to the north so that they have a less elevation, and the sandstone area to the east disappears entirely before we pass very far northward from the south line of the state, so that the great abruptness on the east side of the Flint Hills gradually declines as one travels northward, until it practically entirely disappears and the customary series of terraces and escarpments so common in the Coal Measure area takes their places.

The Carboniferous of Kansas is therefore a great plain the surface of which has been cut into valleys and streams and into great escarpments on the uplands. Wherever we look there are ever-changing scenes before us, scenes dependent in origin on the combination of stratigraphic conditions, surface inclination, and the erosive action of the elements, yet scenes which are pleasing to the eye and satisfying to the mind on account of their ever-varying beauty and suggestive nature. They are the smooth and even poetry of nature rather than the rugged and the strong. They suggest greater scenes, higher hills and deeper valleys, because they are such, only in miniature. "They lack the overpowering immensity of the vast erosions of the west. They do not stagger our imagination by the magnitude of the phenomena. So, as well. they do not discompose our study with sentiments of awe and wonder. They lie within the range of easy comprehension. They are unimpassioned lessons on the methods by which the once expressionless face of the land was carved into pleasingly diversified relief."*

*Chamberlin and Salisbury: Sixth An. Rep. Director U. S. Geol. Sur., p. 224.

CHAPTER XI.

THE COAL FIELDS OF KANSAS. (Preliminary.)

BY ERASMUS HAWORTH.

AREAL EXTENT OF THE COAL FIELDS.

According to the Report of the State Mine Inspector for 1894, twenty different counties in the state have produced coal in sufficient quantities to be considered of commercial value. Five of these are located west of the Coal Measure area, and produce the brown coals, or lignite, in small quantities. The remaining fifteen are located in the Coal Measures proper, and are:

Atchison.	Chautauqua.	Crawford.	Labette.	Lyon.
Bourbon.	Cherokee.	Elk.	Leavenworth.	Osage.
Brown.	Coffey.	Franklin.	Linn.	Shawnee.

It will be seen that they are widely scattered over the eastern part of the state. To this list a few names should be added to correctly represent the geographic extent of workable coal within the state. The report above referred to included only those counties in which coal mining was actually conducted to a greater or less extent during 1894. The extent of the coal, however, is not dependent upon cheap freight rates nor proximity to thicker and better veins, while the markets, and consequently the mining operations, are. The following counties are known to have considerable coal in them, and should be added to the above listed fifteen:

Douglas.
Montgomery.
Neosho.
Wilson.

Each of these has coal to a sufficient extent to justify local operations, usually by the "strip-pit" method. In some of them the mining is practically discontinued on account of the cheap coal shipped in from the larger mines; while could the same coal be located in the western part of the state it would be a fortune to its possessors. The coal beds of Douglas county may be used as an example to illustrate this. A fair quality of coal in veins of from 12 to 16 inches in thickness was formerly mined to a considerable extent in half a dozen or more localities a few miles to the southeast of Lawrence. But with equally good or better coal shipped from Leavenworth and placed upon the retail market at from $2.75 to $3 per ton, the local mining had to be abandoned, excepting here and there where a few farmers obtained their winter's supply of fuel.

In the counties above enumerated the coal is or has been principally mined at or near the following places:

Atchison.—About two miles south of the city of Atchison; the vein has an average thickness of 15 inches; mining operations began in 1893.

Bourbon.—The mines are principally operated to the southeast, east and northeast of Fort Scott, and the coal is known in the market as the Fort Scott "red."

Brown.—Mine on Roy's creek in northeast part of county, near White Cloud in Doniphan county. The vein is about 16 inches thick, and quality of coal good. Operated for local trade.

Chautauqua.—Mines located near Leeds in the northwest part of the county. The operations are principally conducted to supply the local trade. The vein is from 12 to 18 inches thick, and therefore will not admit of operations for the general market.

Cherokee.—This is the second heaviest producing county in the state. The principal mines are located in the environs of Weir City, Cherokee and to the southwest, where three different veins are operated, and farther to the southeast in the vicinity of Columbus, Crestline,

and Tehama, where a 14-inch vein is operated for local consumption. At least four different veins of coal are operated in the county.

Coffey.—Mines located in the vicinity of Lebo. The coal is 14 inches thick and operated for local trade.

Crawford.—This is the heaviest producing county in the state. The mines are situated around Pittsburgh and to the northeast and southwest. Two veins are usually operated and in some places three.

Douglas.—Mining operations almost abandoned. Mines located in the vicinity of Sibley and Blue Mound. The coal vein is from 12 to 18 inches thick, of fair quality, and formerly supplied a considerable local demand, but has been driven out of the market by cheaper coal shipped in from Leavenworth and other places.

Elk.—Small quantities of coal have been found in the vicinity of Grenola, which has been mined to a limited extent for the local trade.

Franklin.—Coal of a good quality and apparently in great quantity exists in different localities to the west and southwest of Ottawa. It is mined principally near Ransomville and Pomona, and supplies the country trade; is extensively teamed to Ottawa, and limited quantities are shipped into the general market.

Labette.—The coal is found in the vicinity of Oswego and to the north. It is in veins about 15 inches thick, and is mined by the "strip-pit" method to supply the local market.

Leavenworth.—A 22-inch vein of coal is mined in and about Leavenworth city by shafting to a depth of between 700 and 800 feet. This county ranks third in the per cent. of its output.

Linn.—The coal in this county is obtained from Pleasanton, Boicourt, La Cygne, Mound City, and a few other places, usually by shafting, but sometimes by the "strip-pit" method. The county ranks fifth in output for the state.

Lyon.—Years ago small deposits of coal were found in the east part of the county which were operated for the local trade. Recently, however, the operations have been abandoned.

Montgomery.—Considerable coal exists in this county to the southeast of Independence, and also to the northeast towards Neodesha. It is only mined locally, and the cheaper fuel from the larger mines has almost put a stop to this.

Neosho.—Thayer is the center of the coal-mining district in this county. The mines are principally located to the west near the border of the county. The coal vein is from 15 to 20 inches thick, and large quantities are obtained for Thayer and surrounding towns, and for the country trade.

Osage.—Coal is mined at many points along the Atchison, Topeka & Santa Fe railway between Topeka and Emporia, with Carbondale, Scranton, Burlingame and Osage City the principal mining centers. The mines are operated by both the "strip-pit" and the shafting methods. This county stands fourth in per cent. of output.

Shawnee.—The mines are located just west of Topeka and at Silver Lake and Dover. Mining is done by both shafting and drifting. The coal veins average about 13 inches in thickness.

Wilson.—The coal is situated to the southeast, east and northeast of Neodesha. The mines are operated quite extensively for local trade. The veins vary from 12 to 18 inches in thickness, and furnish coal which is placed upon the market at almost as low rates as anywhere in the state.

THE GEOLOGICAL POSITION OF THE COAL BEDS.

The Cherokee Shales.

More than 88 per cent. of all the coal mined in the state during 1894 came from the Cherokee shales situated at the base of the Lower Coal Measures. These shales contain many different veins of coal, in fact they are so numerous, were all the lesser ones considered, that probably they would reach twenty or thirty in number. The veins which are worked to a considerable extent in Cherokee county are only four, while to the north in Crawford county only three. About 175 feet above the base of the shales is the Columbus coal. The vein is variable in thickness, but will average from 12 to 15 inches. It lies just under a relatively heavy sandstone which caps the plateau and hills east and southeast of Columbus. The sandstone is cut through in almost every quarter-section by one or more little streams or ravines so that the coal is exposed along the brow of the hill in dozens of different places. The coal bed seems not to be uniform in this respect, so that occasionally it is wanting in areas covered by the sandstone. This coal vein was operated in

the early days of the settlement of Cherokee county several years before the heavier veins above were discovered.

Near the middle of the Cherokee shales the heaviest vein of coal known in the state occurs. It is extensively mined along the belt reaching from a few miles southwest of Scammon to beyond the east line of the state by way of Weir City, Pittsburgh, and other prominent mining towns. It outcrops to the southeast and dips to the northwest at about an average of seventeen feet to the mile. It is usually known as the lower Weir City-Pittsburgh coal. Its thickness, which is remarkably uniform, averages fully 40 inches, with an occasional maximum thickness of 4 feet or more. It is also the best coal in the state as will be shown near the close of the chapter. The northwest limit of this heavy coal seam is not fully determined. Deep borings at Girard show that it does not occur there. There is a general local feeling that it has quite narrow limits in a northwestern direction, but there are some indications that it extends much farther to the west and northwest than has usually been supposed. Above the heavy vein at a distance varying from 30 to 60 feet a second or upper vein is located. It has an average thickness of from 25 to 30 inches, and is mined in many places throughout the coal-mining territory. The quality of the coal produced is almost as good as that of the lower vein. In numerous places in the northwest part of Cherokee county, and reaching over into Crawford county, a third vein of coal is found ranging from 14 to 20 inches in thickness which is mined in many places by the "strip-pit" process. It is particularly easily reached along the eastern border of the Lightning creek valley.

In the extreme southwestern part of Cherokee county, and across the line in Labette county at various places along the Neosho river, quite a number of different coal seams occur, all of which lie within the Cherokee shales. Coal is mined from different ones in the vicinity of Oswego, and for several miles both north and south, at different places in the vicinity of Chetopa, and at other points in the Indian Territory near by.

These different coal seams are not perfectly uniform in vertical position, but they do not vary any more than coal seams usually do. In fact the two heavier ones vary much less than is customary with

similar coal seams throughout the Mississippi valley. The marsh or lagoon in which the coal plants were collected had an unusually level and even bottom, and it must have been at least twenty or thirty miles in length, for good workable coal is found continuously throughout that great a distance.

Farther north, in the vicinity of Fort Scott, coal is found within 8 or 10 feet of the summit of the Cherokee shales. The vein averages about 13 inches in thickness, but in places it is a little more. It is so close to the "cement" rock that usually the latter has to be removed to obtain the coal. The numerous creeks and little ravines for miles around Fort Scott have cut down through the "cement" rock, leaving the coal exposed on all the banks. It has been mined literally in hundreds of places, by the stripping process, the coal having been followed back into the bank ten, twenty, thirty or more feet, dependent upon the thickness of the covering. The coal follows the Oswego limestone southward as it rises into the high anticlinal ridge towards Pittsburgh, throughout all of which distance it has been mined. Along the highest parts of the divide it is no unusual sight to see the "stripping-pits" from which the coal has been taken.

As shown in chapter II, the Cherokee shales extend north to Leavenworth and beyond, where the Leavenworth coal is found at about the middle of their thickness. In sinking the shaft for operating the mines numerous coal seams were passed before the one which furnishes the coal, and by drilling it was learned that at still greater depths other coal of equally good quality and thickness exists. In position, therefore, the Leavenworth coal is about the same as the Pittsburgh-Weir City coal beds. The records of the various drill holes which have been sunk between Pittsburgh and Leavenworth show that there is more or less coal scattered throughout the whole distance, as a careful study of plate II will show. It should not be understood, however, that the Leavenworth coal seam is a continuation of either one of the Pittsburgh seams. Such would be exceedingly improbable on the face of it, and the various drillings referred to show conclusively that the two seams are in no sense of the term continuous. Yet throughout the whole of the Cherokee shales period the conditions in general were favorable for the

growth and accumulation of coal-forming materials, so that in the aggregate vast quantities of the material were formed. According to the estimates given in the Report of our State Mine Inspector for 1893, the total output of coal from the Cherokee shales aggregated 85.79 per cent. of the total output for the state, and for 1894 it had increased to 88.79 per cent. It may reasonably be stated that this not only shows how the coal-mining operations are conducted at present, but also gives a fair indication of the way we may reasonably expect them to be developed in the future. The Cherokee shale beds are *par excellence* the great coal-producing formations of the state.

The Pleasanton Shales.

Above the Cherokee shales little coal exists anywhere in the state below the Pleasanton shales. In a few places small amounts have been seen in the shales between the Oswego and the Pawnee limestones, but it has not been mined at any place so far as known to this Survey, excepting at one point to the southwest of Fort Scott mentioned by Bennett in chapter IV. But when the Pleasanton shales are reached large quantities of coal of an excellent quality are found at their very base, or within less than 20 feet of the Pawnee limestone, which places it only about 100 feet above the top of the Cherokee shales. The principal mines are located at Pleasanton, Boicourt, and La Cygne, at which places the coal is reached by shafting to a depth of from 50 to 90 feet, the exact distance varying considerably with the surface contour. The vein is from 30 to 34 inches in thickness, so that it can be extensively mined with profit.

In other places, particularly around Mound City, still within the Pleasanton shales, other seams of coal are found which are worked either by the stripping process or by drifting. To the south of Pleasanton, all the way to Fort Scott, coal is frequently mined locally. At some of the mines the coal seam is from 20 to 30 inches thick, but usually from 15 to 25 inches. The exact geologic horizon of many of these places has not been determined. Some of them should undoubtedly be correlated with the Fort Scott "red" coal, and others probably with the Pleasanton coal, while Mr. Bennett is

inclined to believe that at some of the mines the coal is in the shale between the Oswego and the Pawnee limestones.

The Thayer Shales.

Above the Pleasanton shales the next coal of any note lies within the Thayer shale beds, the base of which will average about 500 feet above the summit of the Cherokee shales, or 950 feet above the base of the Coal Measures. This coal is particularly noteworthy on account of its being the lowermost coal in the Upper Coal Measures, as the divisions are made by this Survey. It is mined at many intervening points all the way from Independence to and beyond Thayer. Southeast of Independence the principal vein is located high up in the shale bed, as is also the coal at Brooks and Thayer, but in other places to the southwest of Thayer towards Neodesha it would seem the coal is lower. It is quite certain, therefore, that two or more coal seams occur in these shales which probably are separated from 50 to 75 feet vertically.

The amount of coal in the Thayer shales is very considerable and the quality good. Almost all of the community for many miles around is supplied with all their fuel, including the various towns and villages along railroad lines.

The Lawrence Shales.

In passing upwards from the Thayer shales no more coal of any importance is found until the Lawrence shales are reached. They being about 1,400 feet above the base of the Coal Measures, and the coal within them is from 50 to 100 feet above their base. The coal is most abundant in Franklin county, but reaches northward into Douglas county as well. It is most extensively mined to the west of Ottawa, here and there over an area of many square miles. The coal seam is from 14 to 16 inches thick, and the coal is of fair quality, so that when used it compares quite well with the coal of the general markets. The mining is carried on by shafting and drifting. From the mines it is teamed to Ottawa and other neighboring towns, and is loaded on cars at Pomona or Ransomville, and shipped into the general market.

The Douglas county mines are almost entirely abandoned at

present. Years ago, before the coal of the general markets became so reasonable in cost, mining operations were carried on in a dozen or twenty different places over a large area to the southeast of Lawrence. The coal has the same horizon occupied by the Franklin county coal, but is not quite so heavy, ranging from 10 to 15 inches in thickness, and consequently cannot be placed on the general markets in competition with other coals at the prices now ranging.

The Atchison coal occurs in the Lawrence shales near their top, or within about 50 feet of the Oread limestone. The vein is from 16 to 18 inches thick, and the coal is good in quality.

The exact location of the Brown county coal has not yet been determined, but probably it is nearly on a level with the Topeka coal, or the Osage coal.

Although other portions of the state have the surface covered with the Lawrence shales, yet, so far as learned, they do not contain coal in sufficient quantity to justify mining.

The Osage City and Burlingame Shales.

The coals occurring in these shales are remarkable for constituting so extensive a deposit at so high a point within the Coal Measures. They are located 2,200 feet above the base of the Lower Coal Measures, yet in quantity and quality the coal will compare tolerably well with many coals in the Mississippi valley obtained from much lower horizons. The total output in 1894 from this horizon reached the large quantity of 7,754,775 bushels, equalling 8.58 per cent. of the total output of the state.

The mines are principally located in Osage county, along the line of the Atchison, Topeka & Santa Fe railway between Topeka and Emporia, at Carbondale, Scranton, Burlingame, Osage City, and other places. The coal seam outcrops to the southeast and is therefore first mined by stripping. When the dip takes it too far under the surface to admit of profitable mining in this way, the ordinary shafting process is employed. The coal averages about 16 inches in thickness, but in many places exceeds this considerably. The depth at which it is reached of course will depend upon the position with reference to the outcropping and the particular surface contour.

Beyond the limits just given coal belonging to this same horizon has been mined in Coffey county near Lebo and in Lyon county along its eastern line. Thin seams of coal are found in Greenwood county near Madison and southward, and in Elk county around Grenola, also in Chautauqua county at Leeds. At the latter place considerable mining is done.

North of Osage City the same coal is mined near Topeka, and another coal 100 feet higher up at Dover and Silver Lake, two points which lie so close to Topeka that they are usually classed with it. Beyond this to the northeast traces of coal have been found in Jefferson county, Brown county, and at a few other points, which presumably should be correlated with the Osage City-Burlingame coal.

Above the Osage City horizon no coal in paying quantity has been found in the Coal Measure area of the state, excepting the one just named at Dover and Silver Lake.

RESUME OF STRATIGRAPHY.

We have now mentioned all the coal-producing horizons in the Coal Measures of the state, which may be summarized as follows:

Coal-bearing Horizons of Kansas.

1. Cherokee Shales: Located at base of Coal Measures, 450 feet thick.
   Coals: Columbus coal; Weir City-Pittsburgh lower and upper; strip-pit coal in northern part of Cherokee county; various coals around Oswego; Leavenworth coal.
2. Pleasanton Shales: Located above Pawnee limestone and below the Erie limestone, 235 feet thick, with base 550 feet above base of Coal Measures.
   Coals: Pleasanton; Boicourt; La Cygne; and Mound City coals.
3. Thayer Shales: Located between the Iola and Erie limestones, from 100 to 250 feet thick, with base about 1,000 feet above base of Coal Measures.
   Coals: Thayer coal; Brooks coal; Neodesha coal; and Independence coal.
4. Lawrence Shales: Located between the Garnett and Oread limestones, from 200 to 300 feet thick, with base about 1,400 feet above base of Coal Measures.
   Coals: Franklin county coal; Douglas county coal; and Atchison coal.
5. Osage City and Burlingame Shales: Over 100 feet thick, located above Topeka coals, and about 2,100 feet above base of Coal Measures.
   Coals: Chautauqua and Elk county coal; Coffey and Lyon county coal; Osage City coal; Scranton coal; Burlingame coal; Carbondale coal; Dover and Silver Lake coal; Jefferson county coal; and probably the Brown county coal.

PHYSICAL AND CHEMICAL PROPERTIES OF KANSAS COALS.

But little work has been done upon the Kansas coals in the way of exact physical tests and chemical examinations. Professor Blake,

of the department of physics in the University, years ago made a few tests of a number of varieties to determine their steam-producing properties. The results were published in the Transactions of the Kansas Academy of Science, volume XI, page 46, 1888, the summary of which is here reproduced in full:

"*Summary.*

"From these results, the Kansas coals thus far examined are to be arranged in the following order as regards their evaporative powers:

(NOTE.—About one-half the evaporating powers here given will be obtained in practice.)

Order	Name of coal.	Table.	Pounds water evaporated per pound coal.	Duration of burning, seconds.	Calories gram—degrees centigrade.
1	Cherokee	A.	13.42	65	7206
2	Fort Scott	C.	13.20	60	7088
3	Linn county	E.	12.76	65	6852
4	Cherokee, upper vein Leavenworth	B. D.	12.54	50 75	6734
5	Franklin county	G.	12.32	125	6615
6	Osage county	F.	12.10	115	6498
7	Cloud county	H.	9.90	135	5316
	For comparison: Best Indiana block (Clay county)	....	14.43	....	....

In the State Mine Inspector's Report for 1893, page 179, a table is given comparing the relative values of coals from many different parts of America with a cord of standard oak wood. This might be called a comparison of the relative heating capacity of the different coals. This test was made by the United States Quartermaster-General, and gave the following results:

Table Showing Number of Pounds of Coal Equal to One Cord Standard Oak Wood.

	Pounds.		Pounds.
Weir, Kas., lump	1,988	Linton, Ind	2,698
Trinidad, Colo	2,066	Lexington, Mo	2,734
Pittsburg, Kas	2,069	Spring Valley, Ill	2,751
Litchfield, Kas	2,069	Girard, Ill	2,840
Weir, Kas., mine run	2.165	Branch, Ill	2,852
Leavenworth, Kas	2,307	Hocking Valley, Ohio	2,971
Canon City, Colo	2,323	Lyford, Ind	3,015
White River, Wyo	2,323	Streator, Ill	3,076
Rich Hill, Mo	2,369	Boulder Valley, Colo	3,176
Pleasant Hill, Utah	2,407	Burlingame, Kas	3,301
New Kentucky, Ill	2,477	Scranton, Kas	3,418
Gallup, N. M.	2,489	Mitchell, Colo	3,645
Mount Olive, Ill	2,641	Osage City, Kas	3,710
Ladd, Ill., third vein	2,660	All Pennsylvania anthracite	1,700
Fort Scott, Kas	2,670	Cerrillos, N. M., anthracite	1,657

The chemical examinations were made by Professor Bailey, of the University, and were also published in the Transactions of the Kansas Academy of Science, volume XI, page 46. He determined the amount of water, the volatile matter, the fixed carbon, and the amount of ash. The following table gives the results obtained:

The *averages* as given above are collected in the following table:

Name.	Water.	Volatile.	Fixed carbon.	Ash.
Cherokee	1.94	36.77	52.45	8.84
Cherokee (upper vein)	2.08	35.32	48.64	13.96
Fort Scott	2.94	41.76	47.55	7.75
Leavenworth county	2.69	39.21	47.41	10.69
Linn county	2.07	39.42	46.89	11.62
Osage county	6.76	41.59	40.86	10.79
Franklin county	7.55	44.40	37.68	10.37
Cloud county	13.70	46.14	28.52	11.64
Pittsburg, Pa.	1.31	36.61	54.17	7.91
Nebraska	4.93	38.17	49.44	7.46
Warren county, Mo.	6.75	36.40	45.75	11.10

It is desirable to have the two factors, water and ash, as low as possible, for neither of them can be of any value as a fuel. The relative amounts of volatile matter and fixed carbon should vary according to the use to which the coal is to be put. For making illuminating gas a high per cent. of volatile matter is desirable, but for evaporating and general heating purposes, and for coke making, the greater the amount of fixed carbon the better. Doctor Day has published tables comparing the per cent. by weight of coke obtained from 100 parts of bituminous coal from different parts of America. From his report of 1893 on the "Mineral Resources of the United States," page 418, it is learned that the average per cent. of coke produced from the Kansas coals was 62.8, while the highest of any was 66.7 per cent., from the Illinois coal.

From the foregoing tables of both the physical and chemical properties a few conclusions may be drawn. First, it may be considered established that the Kansas coals compare very favorably indeed with the bituminous coals of other states within the Mississippi valley, and fairly well with the soft coals of Ohio and Pennsylvania. Second, it will be seen that in every desirable respect the coals of the Cherokee shales are the best in the state, and that in general the higher the geologic position of any coal the poorer the grade of coal. Yet it may also be concluded that, in comparison with many other coals, our highest, the Osage City, is a good coal.

COMMERCIAL VALUE OF KANSAS COALS.

The commercial value of coal is dependent upon many factors, the most important of all of which is the rate at which outside coal can be imported if the local production does not equal the demand, and the character of the market to be reached provided the local production exceeds the demand. Thus, in this state the local production far exceeds the home demand in almost all places where coal is mined from the Cherokee shales, the Pleasanton shales, and the Osage City shales, while at almost all other points where it is mined the output falls short of supplying the local trade. The only way, therefore to compare coal outputs is to consider the bushels or tons. The following table has been arranged from data taken from the report of the State Mine Inspector for 1893, page 83, and for 1894, page 42:

Table showing Statistics on Production of Coal for 1893 and 1894, Arranged Geologically.

Geologic formation.	County.	Number of bushels.		Per cent. of state output.		Estimated value.	
		1893.	1894.	1893.	1894.	1893.	1894.
	Bourbon	475,000	480,000	.659	.531	$33,250 00	$33,600 00
	Cherokee	20,194,898	25,915,350	28.040	28.705	1,009,704 90	1,295,767 50
Cherokee Shales	Crawford	34,431,627	45,245,900	47.790	50.117	1,721,581 35	2,262,295 00
	Labette	100,000	85,000	.139	.094	9,000 00	7,650 00
	Leavenworth,	6,509,463	8,441,100	9.035	9.349	423,115 09	548,671 50
Pleasanton Shales	Linn	1,852,119	1,461,900	2.571	1.619	92,605 95	73,095 00
	Montgomery ..						
Thayer Shales	Neosho	No statistics given.					
	Wilson						
	Franklin	551,290	400,525	.765	.443	44,103 20	32,042 00
Lawrence Shales	Douglas	No statistics given.					
	Atchison	2,375	62,500	.003	.069	213 75	5,625 00
	Brown	....	50,000	......	.055	....	4,500 00
	Chautauqua ..	44,000	38,000	.062	.042	4,400 00	3,800 00
Osage City and Burlingame Shales	Coffey	375,000	87,500	.520	.096	32,812 50	7,875 00
	Elk	....	20,000	......	.022	....	2,000 00
	Lyon	....	9,000	......	.009	....	900 00
	Osage	7,018,946	7,400,275	9.742	8.197	529,899 61	555,020 62
	Shawnee	190,835	150,000	.265	.166	22,900 20	17,500 00
Totals	....	71,745,553	89,847,050	99.581	99.513	$3,923,626 55	$4,850,341 62
Coal from western counties	....	302,715	433,300	.419	.487	36,725 09	49,433 00
Grand totals	....	72,048,268	90,280,350	100	100	$3,960,351 64	$4,899,774 62

PROBABLE FUTURE OF COAL MINING IN KANSAS.

There are good reasons for believing that coal mining in Kansas will increase with comparative rapidity during the coming years. There can be no reasonable doubt that the quantity within the Coal Measure area is much greater than has been usually estimated

by those interested in such matters. The records of the various deep wells drilled by those prospecting for oil and gas show than in many places coal in considerable quantity was passed through, which might often be mined were there a sufficient demand for it. Further, as has been shown in these pages, our state is full of thinner seams of good coal which cannot now be mined on account of the low price of coal. But should the price advance only from 1 to 2 cents per bushel many of them now untouched could be successfully operated. There is, therefore, little ground for apprehension regarding the exhaustion of our coal mines within a few centuries, or of the material advance in price.

Many inquiries have been made of the Survey regarding the probabilities of deep borings reaching coal in the west-central portions of the state. We are not now in possession of sufficient data upon which to base predictions that will be of any special value. In general it may be said that the Lower Coal Measure strata maintain their thickness westward much better than had previously been supposed by geologists in general. The Cherokee shales maintain almost their full thickness to as far west as Neodesha and Fredonia, with considerable quantities of coal, as is shown by the 27-inch vein at Cherryvale, and this indicates that possibly they and other formations may continue westward for 100 or 200 miles more. We are in possession of no authentic records of deep wells further west than Fredonia. Could a few wells be drilled about Wichita, Hutchinson and to the north which would pass almost to the base of the Coal Measures they would throw much light on the general stratigraphy of the deeply buried formations, and, whether they passed through coal or not, would be a great help in the intelligent prediction of the probable conditions of the presence or absence of coal in any considerable quantities. It is earnestly hoped that in the future accurate records of all deep wells within the state will be permanently preserved. At present little encouragement can be given to the hope that coal in paying quantities could be reached in those localities by shafting.

CHAPTER XII.

OIL AND GAS IN KANSAS. (Preliminary.)

BY ERASMUS HAWORTH.

HISTORY OF DEVELOPMENT.

The history of the discovery and development of oil and gas in Kansas may be divided into three parts: Part first, dealing with those indications which led up to the further development; part second, with what may be termed the first stage of development; and part third, the recent period of development, which continues to the present time.

First.—In a number of different places in the state the earliest settlers learned from Indians that "oil springs" existed. Some of them were counted of wonderful efficacy by the Indians, and were regularly visited by them for the purpose of obtaining material to be used by the medicine men in their various forms of "practice." They were principally located in Miami and Wyandotte counties, and possibly some were known outside. The first settlers naturally became much interested in such occurrences, particularly as this was a period during which the development of oil in the Pennsylvania

region was progressing so rapidly. Wells were drilled in the vicinity of Wyandotte which furnished considerable quantities of gas, a product at that time almost entirely unknown in America. As early as 1860 Mr. G. W. Brown, of Paola, began prospecting for oil, but the work was abandoned on account of the political difficulties which soon arose. In the vicinity of Mound City a few wells were drilled about the same time, each of which produced a small quantity of both oil and gas, but nothing considered of any special importance. In the early days after the war the citizens of Paola, principally through the efforts of Hon. W. R. Wagstaff, W. T. Shively, and others, engaged the services of Prof. G. C. Swallow, then State Geologist for Kansas, to make a survey of Miami county with special reference to the probability of finding oil. His report, a pamphlet of 24 printed pages, was full of encouragement, as may be shown by the following short quotation: "The facts seem sufficient to convince anyone familiar with indications of the development of petroleum in the productive regions of the country that it exists in large quantities in this county." With such encouragement as this, companies were formed and considerable prospecting done in the environs of Paola, but with indifferent success.

The surface indications of petroleum were too wide-spread in character to be confined to the limits of the counties named. As far south as Cherokee county considerable attention was given to the subject by the early settlers immediately after the close of the war. The prominence of the indications in the western part of the county may be judged from the fact that a small stream was named "Tar creek," and the current belief was that should prospecting be done vast quantities of oil would be obtained.

It will thus be seen that from the earliest days of Kansas history there has been a popular and wide-spread faith in the ultimate development of a great oil and gas industry in the eastern part of the state.

Second.—The second period of our history may include the time from about 1871 or 1872 to 1890. During this period a great deal of drilling was done in different places, principally by local companies and by drillers of limited experience. Paola was looked upon as the central portion of the oil and gas territory. In 1882 prospecting

was again renewed in Miami county, and gas was found in the wells which were drilled about seven miles to the northeast of Paola, a locality to which the prospector had been drawn on account of the traces of oil which were found on the spring waters at that particular place. The result of this prospecting was that sufficient quantities of gas were found to be piped to the city and introduced as a source of light and heat in the residence and business houses of Paola. Prospecting was continued all around the city, east, north, and west, so that practically as large a supply of gas as could be consumed was obtained and has been maintained to the present time. Some of the wells produce considerable quantities of oil. One of these, for example, yielded 15 barrels per day for quite a while.

Drilling was prosecuted in Wyandotte county quite irregularly during this second period. Sometimes it was interrupted by litigation; sometimes by discouragement from partial failures in obtaining gas; and sometimes from other causes.

In 1873 a well was drilled at Iola, the "Acres well," which produced sufficient gas to attract considerable attention and which was doubtless a factor in encouraging prospecting in other localities. The prospecting was rapidly extended to the different counties throughout the whole southeastern part of the state, so that up to 1890 no less than a dozen towns and cities were principally or wholly supplied with both light and fuel for all domestic purposes.

Third.—The third period of history begins with the introduction of eastern money and eastern companies into our oil and gas territory. Having been attracted by the fair success obtained by local companies, as above outlined, it was an easy matter for those who began it to induce companies of experience and means to come to Kansas and engage in prospecting for both oil and gas. Of these the company which has done the most to date is the Guffey & Galey Company, of Pittsburg, which makes its headquarters at Neodesha, in Wilson county, and the Forest Oil Company, which has recently bought the Guffey & Galey interests. They have leased large territories and have drilled many wells, scattered over a territory bounded by Chautauqua county on the southwest and Miami county on the northeast, and have obtained sufficient success to justify them

in making further improvements, which seem to indicate that the oil and gas industry in Kansas is a permanent matter. Next in importance of work already performed is the Palmer Oil Company, of Cleveland, Ohio, which has likewise obtained leases over large areas and has begun prospecting in a vigorous manner. Other eastern companies have also entered the field and have secured leases on a large number of farms, and are making arrangements to begin development at an early day. The territory which has been most productive during the recent period is located further to the southwest, with Neodesha and Thayer in its center.

The present condition of the industry may be summarized as follows: Natural gas is now obtained in sufficient quantities to be used wholly or partially for lights and fuel in the following cities: Wyandotte, Paola, Osawatomie, Fulton, Iola, Humboldt, Cherryvale, Neodesha, Independence, Coffeyville; and has been obtained in more limited quantities at Fort Scott, Girard, Pittsburgh, and other places. Oil is now being obtained in considerable quantities at Peru, Neodesha, Thayer, Independence, Osawatomie, and in lesser quantities at some other places. It is difficult to state the amount of oil obtained. The development is still in the prospecting stage, and in many places connections have not been made between wells and the central tanks, so that the flow is suppressed. Quite flattering results have been obtained from the oil wells at Neodesha by the prospecting done by the Forest Oil Company since it bought interests here, so that at this date, February, 1896, there is more cause for encouragement than ever before.

GEOGRAPHIC EXTENT.

The area throughout which oil and gas has been found in greater or less quantities covers about 8,500 square miles, and is located in the southeast part of the state. It may be approximately bounded as follows: From Kansas City draw a line to Lawrence a distance of 40 miles; from Lawrence pass a sinuous line to Sedan, in Chautauqua county. The portion of the state included between these two lines may all be considered as oil and gas territory, except a small area in the extreme southeastern part covered by the Cherokee shales. This is not more than 500 square miles in extent, and may

be approximately limited by passing a line from the southwest part of Cherokee county to the middle of the east side of Crawford county, about 10 miles north of Pittsburgh.

There is not a single county within the limits above mentioned which has not produced either oil or gas, or both. To the northwest of the area a few wells have been drilled, with indifferent success, but prospecting has not been carried to a sufficiently great extent to warrant anyone in deciding that gas could not be obtained over a much larger area to the northwest.

GEOLOGY OF OIL AND GAS.

Thus far in the history of development the total production of both oil and gas has come from the Coal Measure formations. A number of wells have been sunk through these into the Mississippian limestone below, but in no instance have any valuable results been obtained. Both shale and sandstone are productive, the latter being most abundantly so; in numerous cases, however, good flows of gas have been obtained from the shale. It is common here as well as elsewhere to speak of the oil sands or gas sands. From the conditions of stratification already explained in the previous chapters of this Report it will be seen that the occurrence of sandstone is somewhat irregular. Perhaps no well can be drilled which will not pass through an abundance of sandstone so far as quantity of that material is concerned.

The sands are located in each of the great shale beds from the Cherokee shales upward. Those in the Cherokee shales are the most productive. In fact, it may well be stated that in the southeastern area nine-tenths of all the oil and gas have been obtained from the sandstones within the Cherokee shales, yet it is also true that each individual shale bed above this has produced one or the other of those materials. The gas wells at Independence, east of the Verdigris river, for example, obtained all of their oil above the Oswego limestone. The drill penetrated the Cherokee shales, from which their supply of gas is obtained. At Cherryvale gas is largely obtained from the Cherokee shales, but a few of their most productive wells stopped within the upper shale beds. At Coffeyville the gas is obtained in some instances from Cherokee shales, and

in others from the shale beds above. At Neodesha, Thayer, and Iola, the Cherokee shales have been reached in almost every instance before any considerable flow of gas was obtained. The strong wells at Neodesha, and the recent very remarkable well drilled at Iola by the Palmer Oil Company, a well producing seven million cubic feet of gas per day, all were sunk nearly to the base of the Cherokee shales before the heavy flows were obtained. At Paola the productive wells are quite shallow generally, but, as will be seen by referring to plate II, the Cherokee shales are wonderfully thickened here, so that the wells reached their upper surface. This is also true at Osawatomie, at which place the wells usually were drilled to a depth of from 400 to 900 feet. A good illustration of the production of gas by one of the thin shale seams was met with during the drilling at Fulton. One of the wells was started at a place where there was an unusually heavy covering of soil and clay. At a depth of about 40 feet below the surface the thin shale bed lying between the two Oswego limestones was reached, when quite a perceptible flow of gas was obtained.

It will thus be seen that both oil and gas are obtained from included sandstone, or the shale itself, within each of the shale beds from the Mississippian upward to the Lane shales. It is unnecessary here to speak of the geologic positions, the thickness, or the character of these different shale beds, as such have been given in previous chapters.

RELATION OF DEPTH TO PRODUCTION.

It will be seen from the foregoing that the depth at which oil and gas are obtained is dependent upon a number of factors. Where a productive shale bed comes to the surface the leakage has doubtless exhausted the supply long ago, but where it is sufficiently protected to prevent leakage the production will be shallower as the covering is lighter. The relatively barren area in Cherokee county presumably has been eroded to such an extent that the necessary covering has been removed from the Cherokee shales, so that whatever quantity of either oil or gas may have existed there at one time has been principally dissipated through surface leakages. This idea is strengthened by the frequent discovery of small quantities of

gas in the ordinary prospecting for coal, and further, by the indications of oil springs along Tar creek, and other places. This principle may be extended to other portions of the country. Every shale bed comes to the surface along its eastern limits, and consequently is deprived of a protective covering over portions of its area. No instance is known of any considerable quantities of gas being found in those localities, yet numerous cases have been reported of variable amounts of gas escaping from ordinary wells dug to depths of from 30 to 80 feet. Such escapes represent the natural leakage that is taking place over all surfaces which are not protected sufficiently from above. The question, therefore, of the depth at which gas may be reached is one which can be answered only conditionally for any particular locality. It will depend upon the depth below the surface at which gas-producing shale beds may be reached. A correct idea of this may be gained by a study of the different charts accompanying this Report, which accurately represent the underground positions of the various shale beds in the southeast part of the state.

Another factor, however, should be here considered: the great prevalence of salt water throughout the whole gas area may so seriously interfere with the flow of gas that a well which otherwise would be productive is almost entirely barren. When a well has reached a depth of a thousand feet, should gas be obtained in considerable quantities, the presence of large quantities of water would render the well useless unless the gas pressure were sufficient to lift the column of water the full height of the depth of the well. It is therefore quite probable that in many cases could a well be carried to a little greater depth after salt water is reached paying quantities of gas could be obtained were it not for the interference of the salt water. But few paying wells are known which are more than 900 feet deep, while many good wells are less than 600 feet.

IS THE MISSISSIPPIAN SERIES OIL OR GAS PRODUCING?

Little encouragement can be found for penetrating the Mississippian formation in search of oil or gas, although they pass westward under the Coal Measures. The more prominent reasons for

this belief may be summarized as follows: First, the extensive mining operations in southwest Missouri and southeast Kansas have failed to develop even traces of oil or gas, excepting small quantities of an almost solid bitumen which occasionally is found in little pockets and crevices in the ore-bearing rocks. Had the Kansas hydrocarbons been generated below this horizon and driven through it to their present resting-place it seems exceedingly probable that greater indications of it would be met with in the mining operations. Second, at different places, notably Pittsburgh and Girard, wells have been drilled several hundred feet below the base of the Cherokee shales searching for artesian water. At Pittsburgh five such wells have been drilled, the deepest of which went over 1,000 feet below the Cherokee shales. Neither salt water, oil nor gas was found in any of them, the water obtained being used as a supply for the city. Pittsburgh is situated near the top of an underground ridge in the surface of the Mississippian rocks, which probably is an anticlinal ridge. Should gas ever have passed from below upwards through this heavy limestone some of it would certainly have lodged beneath this anticlinal, and the Pittsburgh wells would have discovered it. The Girard well was similar, but taken to a less depth. It started in the soil covering the Oswego limestone and went 357 feet below the base of the Cherokee shales. It found considerable gas within the Cherokee shales but none below them.

This is a question of great practical importance. It is evident that if the oil and gas were generated within the Coal Measures the leakage where their covering is thin has been so great that nothing more than mere traces could be expected within them. Should they have come from below, however, there may be accumulations of them below the Mississippian limestone which could be obtained by deep drilling. For the reasons above given such prospecting should be discouraged.

THE RELATION OF OIL AND GAS PRODUCTION TO ANTICLINALS AND SYNCLINALS.

The details of the exact number and location of the various anticlinals and synclinals in the oil and gas territory are so little known

that it would be premature to draw any general conclusions at the present time regarding the relation of the flow of oil or gas to those structures. The general dip of all the formations is towards the west and northwest, but along with this there are many reversals of directions, and anticlinals and synclinals trending in different directions. The indications are that such irregularities in the surface are too limited in extent and in angle of inclination to have any considerable influence on the accumulation of either oil or gas. If a given limestone has a slight irregularity of position due to the uneven surface of the ocean bottom on which it is deposited the formations beneath it might not partake of such irregularities. In such cases it is difficult to understand how its particular condition of dip would have any bearing on the accumulation of gas below it. As was pointed out in chapter IX, there is a total absence of conditions resulting from any very considerable orographic movements, and consequently a particular shale bed which is gas-producing may have the stratifications within it entirely independent of the slight anticlinals and synclinals noticeable in the overlying limestone.

By way of observation it may be said, that so far as has been determined there is a lack of harmony in the results obtained on this subject. Cherryvale is located on a slight anticlinal ridge with an axis trending northwest and southeast which itself dips to the northwest. Whether this has any influence on the accumulation of gas at that place may well be doubted. At Neodesha all the strata seem to be dipping to the west about 17 feet to the mile. It has not been ascertained whether or not there is here a slight anticlinal with axis pointing towards the northwest. Paola is in one of the greatest synclinal troughs there is in the state, yet large quantities of gas have been obtained from this synclinal trough.

It would therefore seem that, so far as our present knowledge of the subject would indicate, there is little if any relation between the location of anticlinals and synclinals and the accumulation of either oil or gas.

PHYSICAL AND CHEMICAL PROPERTIES.

Until quite recently we have had few data regarding the physical and chemical properties of the oils and gases of Kansas. The lubricating oils sold from Paola were partially examined and were found to possess superior proprieties for lubricants. Other companies have had samples tested at the refineries, and during the past year Prof. E. H. S. Bailey, of the chemical department of the State University, has made a large number of careful examinations of both oil and gas. His paper is now passing through the press, and will soon appear in the report of the Kansas State Board of Agriculture. Through his kindness the following extracts have been made from his manuscript. The specific gravity of the oil was taken; then it was subjected to fractional distillations and the flash point and gravity for each distillate was determined. In the following tables the left-hand column gives the range of temperature in the centigrade or Celsius scale at which the distillate was obtained, the second column the flash point of same, the third column the specific gravity, and the fourth column the amount distilled expressed in cubic centimeters. A glance at this column will show at what temperatures the larger portion of the oil was distilled, and therefore the general character of the oil.

No. 1. Main Well at Neodesha. G.=0.835.

Temperature C.	Flash point C.	Specific gravity.	Amount distilled.
40 deg. to 110 deg.	Below 26 deg.	0.7058	61 c.c.
110 " to 150 "	Below 26 "	0.7314	82 c.c.
150 " to 200 "	Below 26 "	0.7778	107 c.c.
200 " to 250 "	Below 76 "	0.8112	77 c.c.
250 " to 300 "	91 "	0.8377	101 c.c.
300 "	Above 100 "	0.8691	215 c.c.

About 14 per cent. of the original volume remained undistilled at the highest temperature to which it could be carried by a gas flame and in a gas flask.

No. 2. Kimball Well No. 2, Neodesha. G. = 0.835.

Temperature C.	Flash point C.	Specific gravity.	Amount distilled.
70 deg. to 110 deg.	Below 30 deg.	0.7002	118 c.c.
110 " to 150 "	Below 30 "	0.7417	178 c.c.
150 " to 200 "	Below 30 "	0.7793	157 c.c.
200 " to 250 "	57 "	0.8099	153 c.c.
250 " to 300 "	Above 95 "	0.8343	210 c.c.
300 "	Above 95 "	0.8739	500 c.c.

About 12 per cent. of the original amount remained undistilled.

No. 3. Hopkins Well, five miles northwest of Neodesha. G. = nearly 1.

Oil very heavy and hard to distill, less than half passing off below 300 degrees.

No. 4. Ordway Well, Thayer. G. = 0.849.

Temperature C.	Flash point C.	Specific gravity.	Amount distilled.
70 deg. to 110 deg.	Below 27 deg.	0.7124	42 c.c.
110 " to 150 "	Below 27 "	0.7374	82 c.c.
150 " to 200 "	Below 27 "	0.7742	70 c.c.
200 " to 250 "	69.5 "	0.8046	115 c.c.
250 " to 300 "	Above 95 "	0.8341	121 c.c.
300 "	Above 95 "	0.8663	250 c.c.

About 12 per cent. of the original amount did not distill.

These four wells may be looked upon as fairly expressive of the physical properties of Kansas oils. Possibly extremes may be found outside these limits, but not to any considerable extent.

The analyses of the gases showed that we have natural gas of most excellent quality when compared with the eastern gas. The following table gives the percentage composition of gas from six different localities, so that we may conclude they well represent the gas of the state:

Components of gas expressed in per cents.	Paola.	Osawatomie.	Iola.	Cherryvale.	Coffeyville.	Independence.
Hydrogen, H	0.00	0.00	0.00	0.00	0.00	0.00
Oxygen, O	0.45	Trace.	0.45	0.22	0.12	Trace.
Nitrogen, N	2.34	0.60	7.76	5.94	2.21	3.28
Carbon-monoxide, CO	1.57	1.33	1.23	1.16	0.91	0.33
Carbon-dioxide, CO_2	0.33	0.22	0.90	0.22	0.00	0.44
Ethylene series, C_2H_4, etc.	0.11	0.22	0.00	0.00	0.35	0.67
Marsh gas, CH_4	95.20	97.63	89.66	92.46	96.41	95.28

The slight differences in above gases amount to but little. So far as they go, however, it will be seen that the Osawatomie gas has the largest per cent. of marsh gas, which is the principal combustible material, and the smallest per cent. of nitrogen, an inert substance, and therefore would be called the best gas.

ORIGIN OF KANSAS OIL AND GAS.

The evidence available from the various conditions under which they now exist points towards an organic origin for the Kansas oil and gas. Their intimate association with the shales, which are so rich in organic matter, would also imply that they are principally derived from vegetation, for our Coal Measure shales are poor in both vertebrate and invertebrate fossils, which indicates that animal life was not very abundant during the shale-forming periods of Coal Measure time. The bituminous character of the shales is therefore principally, or almost entirely, due to the presence of vegetable matter. The absence of oil in the Mississippian series, as already explained in this chapter, would strongly favor the idea that the Coal Measure shales are the formations in which the oil and gas were generated.

If the oil is obtained from the shales it would consequently be of vegetable rather than of animal origin. The chemical composition of the gas, as just given, also indicates the vegetable origin of the gas; for were it of animal origin it probably would have more nitrogen. Also the oil has an absence of that peculiar fetid odor some oils have which is usually regarded as indicative of animal origin.

Its presence in the sandstone beds would by no means indicate that the sandstone formations were the sources from which it was generated but rather that the sandstones act as receptacles for the gas after it is generated. Their porous condition make them, in reality, great underground cavities in which any liquid or gaseous substance may find a resting-place.

PROBABLE EXTENT OF PRODUCTIVE TERRITORY.

The area over which oil or gas or both have already been obtained was outlined in the first pages of this chapter. It might be well to

say a few words regarding the probability of the productive territory being extended to the west. It should be clearly understood at the outset that any remarks that may be made on this subject are only tentative. If our great shale beds pass to the west a considerable distance beyond the limits of the deep wells already bored there is no reason for doubting their bituminous nature. All that we know regarding the conditions of deposition would imply that a considerable amount of organic matter was mixed with them at the time of their formation much farther to the west. This is believed because, as far west as prospecting has been carried, the carbonaceous nature of the shales seems to be maintained with no indication of any considerable decrease. If such is the case, we cannot know of any reason why both oil and gas may not have been produced in the depths of the earth many miles west of the present known limit.

But this should not be used as a basis for hopes of a great productiveness very much farther west. A difficulty is encountered which probably will increase rapidly towards the west. I refer to the almost universal presence of salt water. Naturally with the dip of our strata being as it is, the productive shales and sandstone lie much deeper to the west, and the difficulty produced by the salt water will rapidly increase. The mere fact that both gas and oil are lighter than water is of little avail in such case. The minute pores in the sandstone and the shales through which the gas must pass will be effectually stopped by the great pressure of the water.

Few questions are of more immediate importance to the western cities, like Wichita and Hutchinson, than the question of the probability of obtaining oil or gas by boring. Could a few wells be sunk in these localities to the base of the Cherokee shales much light would be thrown upon the question thereby, and if accurate records were kept and placed in the hands of a competent geologist for comparison with the data contained in this Report a much more valuable estimate could be made of the probabilities in the case. Such wells would have to be sunk somewhere from 2,000 to 3,000 feet deep and would therefore be very expensive, with the chances very great of the salt water preventing any valuable results, even though the gas and oil might possibly exist.

PROBABLE FUTURE OF OIL AND GAS IN KANSAS.

With the favorable results obtained by the prospectors, especially during the last two years, we have good reason for hoping that the oil and gas industry in Kansas will ultimately assume considerable proportions, even compared with the same industry in eastern states. Our productive territory is large, and one or the other of the products seems to be available at almost every place within it where prospecting has been carried to any considerable extent. It is evident that the oil and gas are more uniformly disseminated in Kansas than in any other territory yet developed in America. This augurs well for the future. Prospecting will not be so uncertain as in Ohio and Pennsylvania, where productive areas have such sharp limitations. With our present knowledge of the case, it would seem that there is considerable encouragement for any village or city within the productive area to drill wells expecting to obtain gas in sufficient quantity to be of great importance for domestic purposes. It is not altogether a vain hope, it would seem, to look forward to a time in the near future when all southeastern Kansas outside of the Cherokee shales area will be almost entirely supplied with light and fuel from the oil and gas lying beneath their doors.

CHAPTER XIII.

SURFACE GRAVELS OF THE CARBONIFEROUS AREA.

BY ERASMUS HAWORTH.

Geographic Location of Gravels.
Previously Expressed Views.
Results of Present Investigations.

GEOGRAPHIC LOCATION OF GRAVELS.

Perhaps no county in the eastern part of the state is entirely free from surface deposits of gravel which are radically different in character from those further north belonging to the glacial deposits, and from the various Tertiary gravels found in different parts of western Kansas. The glacial gravels are found in the northeastern counties, but are unknown over the greater part of the state. The gravels under discussion are composed almost entirely of flint, or chert, and are often fossiliferous. They vary in size, ranging from the size of a pea to five or six inches in diameter. Their shape is rounded, but often decidedly angular, and occasionally they have sharp, cutting edges. In color they range from the light chalcedonic varieties through different shades of yellow and red to dark, as river gravels usually do when stained with iron which is in various stages of oxydation. The light buff color greatly predominates.

They are found in beds of various dimensions, and in different positions with reference to the surface. Sometimes they form only a little sprinkling on the surafce; sometimes they form heavy beds from 2 to 3 feet thick at or near the surface and at other times they are buried from 10 to 20 feet beneath a surface soil. Their position is as varied as the surface of the country where they occur. They

are found in the creek and river beds, along the banks of the streams, underlying the rich soils of the valleys, on the uplands and divides, and finally on top of the highest hills in the country.

Geographically they extend from north to south, from east to west, not over all the surface, but so extensively that one may not be at all surprised to find them at any particular place. They are found in great abundance at the northern edge of Ottawa, and almost all along the Atchison, Topeka & Santa Fe railroad from that point to beyond Independence. They are abundant on both sides the Neosho river from its source to its point of leaving the state, and are much more abundant along the Cottonwood river. The court-house at Cottonwood Falls stands on a hill covered with gravel to the depth of 10 feet or more, and they abound for miles in every direction. The most extensive deposits of gravel anywhere in the state are found in the famous Flint Hills area lying between the Walnut and Verdigris rivers near the south line of the state. Masses of flint varying from 2 to 3 feet in diameter to those of small size are so abundant that the name is generally considered to have been well chosen. Gravel in greater or less abundance is found on the surface all the way from the Cottonwood river, which determines the northern extension of the Flint Hills as the term is usually applied, to far beyond the Kansas river to the north. Cursory examinations made from time to time during the past 15 years indicate that similar gravel deposits are found to the south in the Indian Territory and to the east in Missouri, occupying indiscriminately the surfaces of Coal Measures and Mississippian formations. The character of the gravel is largely the same all over the areas mentioned, and the modes of occurrence cannot be discriminated.

PREVIOUSLY EXPRESSED VIEWS.

Such interesting formations as these gravels constitute have naturally attracted the attention of different geologists at various times. One result is that quite a literature has accumulated on the subject, in which one can find many different views on the origin of the gravel and mode of formation of the beds. Without attempting to give an exhaustive review of such literature, a few references

to various articles on the subject may be of interest in this connection. In 1874 Prof. G. C. Broadhead, in describing the surface deposits of Jasper county, Missouri, wrote as follows:* "The material overlying the solid rocks may be referred to local agencies. Solid beds of rock often appear on high ground, and can always be reached within a few feet of the surface. The soil and subsoil, both combined, are not often over 2 feet deep, with downward successions of red clay and gravel for from 4 to 8 feet, to solid rock. The gravel is even sometimes at the surface, and often within a foot depth. A similar succession of loose material is also commonly found at the lead mines. The banks of the streams, also, are similar, of which Center creek exhibits:

No. 1.—1½ feet dark soil.

No. 2.—2 feet red clay.

No. 3.—3 feet gravel bed to the water in creek.

"On the prairie two miles to the southwest of Carthage excavations show water-worn chert pebbles at the surface. At the old mines in section 33, four miles southeast of Carthage, similar pebbles were observed. These were found 60 to 70 feet above Spring river or Center creek; so it is quite evident that no recent agency could have deposited them there. They must therefore belong to the Drift, about its southern limit, but born by currents from some place near by."

In speaking of the surface deposits in Vernon county, he writes:†

"Undoubtedly this country has been subjected to glacial agency at some former period of time. Its results may be seen in the isolated mounds and deep valleys between. The amount of erosion must have been of great force and of long continuance, if we view the mounds and long stretches of distance from one to the other. No drift pebbles were seen on high ground, but some wells exposed rounded gravel and sand. Near Nevada, I heard of a gravel bed containing logs, etc., in a well 16 feet below the surface."

Similarly when describing Bates county Professor Broadhead says:‡

* Missouri Geol. Sur. Rep., 1873-'74, p. 179.
† Missouri Geol. Sur. Rep., 1873-'74, p. 121.
‡ Ib., p. 156.

"That this county has been at some former time subject to extreme denudations is evident from the isolated mounds often seen. Their summits are probably of the same elevation as the higher ridges in the eastern part of the county. There has been a scouring from north to south, leaving isolated mounds protected from destruction by cappings of limestone. The force of the glacial action which has caused this has been such as to bear away all drift pebbles from the surface excepting when on the higher grounds. On the mounds east of Pleasant Gap are often seen quantities of rounded gravel, mostly silicious. The banks of Camp creek have exposed at one place a bed of similar gravel with sand. At Burnett's ferry the banks of the Osage show:

No. 1.—Soil.

No. 2.—12 feet brown sandy clay.

No. 3.—10 feet blue clay.

No. 4.—Bed of rounded silicious gravel."

Later Professor Broadhead referred to the surface gravels of Kansas in different articles published in the Kansas City Review,* in which he gives a good description of their geographic positions, emphasizing the fact that they so often occur on the highest hilltops. He refers the age of the gravel to the Coal Measures, but that of the gravel beds to the "Later Glacial." It will thus be seen that Professor Broadhead, whose observations have been very extensive, attributes the origin of the gravel to the local formations for both the Missouri deposits, and the origin of the beds or layers to the later glacial action. In this respect his views are similar to those of St. John, as is shown by the following quotations:† "To the latter [the modified drift] belong the ordinary superficial deposits spread over the southeastern portion of the state, among which no vestige of true glacial erratics . . . have been detected, whose accumulation was due to the denudation and disintegration of the limestone, sandstone and shaly deposits occurring in the region where they exclusively constitute the evidences of the action of powerful denuding agencies, which may, with much reason, be identified with the Champlain epoch."

* Kansas City Review of Science and Industry, vol. 3, p. 460, and vol. 8, p. 453.
† Report Kansas St. Bd. Agr., 1881-'82, p. 598.

In a later publication he writes:* "In regard to the chert gravel from the Neosho valley near Burlington, Kas., it is perfectly safe to say it comes from the chert beds overlying the heavy building limestone series, well up in the Upper Coal Measure series. . . . It may not be strictly a 'glacial' gravel, although these particular deposits might well have in part been the result of glacial agencies; but they are to be regarded as of local origin, as we can distinctly trace them to their native ledges only a few miles to the west or northwest of their present position in the gravel deposits. . . ." From fossils contained in the gravel, St. John decides they are identical in age with the Coal Measure rocks, many of which contain large amounts of chert.

Professor Mudge, who was so familiar with Kansas geology, visited the Burlington gravel beds in 1871 and expressed the opinion, according to Parker,† that they were the result of "modified drift," whatever that may mean.

The gravel beds in the vicinity of Burlington years ago attracted considerable attention, and an effort was made to introduce the gravels for paving streets, walks, etc. In this connection Prof. J. D. Parker published a number of articles giving descriptions of the character and extent of the deposits. He also sent samples to different scientists and civil engineers, thereby hoping to gain information regarding their age, mode of formation, economic importance, etc. Prof. C. F. Chandler, of the Columbia College School of Mines, wrote that the character of the gravels was such that they would do excellently for macadamizing. Different physicians recommended their use from sanitary standpoints, their color being preferable to that of limestone, which reflects the sunlight to so great an extent that it is objectionable for street-paving purposes. City engineers advised their use for street paving on account of their great durability, so that it looked for a time as though an industry of considerable proportions might spring into existence. Prof. C. A. Shaeffer, of Cornell University, now president of Iowa State University, to whom samples were sent, reported the character of the pebbles, as already given, and added that he had succeeded in identi-

* Private letter to Prof. J. D. Parker published in Kansas City Review, vol. 8, p. 386, 1884.
† Ib., p. 386.

fying included fossils as belonging to the two genera *Fenestella* and *Trematopora.* From this fact he decided that the gravel belonged to the Silurian period. But as these genera extend from the Silurian to the Coal Measures their existence by no means is at variance with the views of others who refer the gravel to the Coal Measures.

In 1884 Judge E. P. West read a paper before the Kansas Academy of Science* entitled, "The Last Submergence and Emergence of Southeastern Kansas from the Carboniferous Seas, or those Effecting the Carboniferous Formations in Kansas," in which he attributed the present topography of the eastern part of the state to the relatively modern submergence below the sea level, during which time, he thought, the valleys were eroded, the terraces formed, and the gravel beds produced. In this paper he was unable to fix a date for either the beginning or ending of the submergence, but subsequently† he decided that the period was the same as that portion of the glacial period during which the Loess was deposited along the Missouri river, and that the submergence involved nearly all of Kansas and parts of Nebraska, Iowa, Missouri, Illinois, Arkansas, Louisiana, Indian Territory, and Texas. He admits, however, that no trace of marine deposits has been found over this vast territory, and seems to rely wholly upon the extent of erosion, and the gravel and other surface deposits for the evidence of such a wide-spread submergence. How well this accords with the generally accepted views of erosion the reader can judge.

RESULTS OF PRESENT INVESTIGATIONS.

It will be seen from the foregoing that the prevailing opinion has been that the gravels themselves originated in the Coal Measure limestone, and that the accumulation of the beds was in some way connected with the glacial period, probably with the heavy floods produced by melting ice.

Our labors the past three summers have demonstrated a few points which may have an important bearing on the subject. First,

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*Published in Kansas City Review, vol. 8, p. 477, and also in Trans. Kas. Acad. Sci., vol. 9, p. 106.

†Kansas City Review, vol. 8, p. 566.

we have become convinced that chert has such a wide-spread distribution in the different limestone systems of the state that transportation has been necessary in but few instances, possibly in none. Could the limestones as now seen be dissolved in a day, the amount of chert left behind would be surprisingly great. Scarcely a single system has been studied carefully which did not contain surprisingly large amounts of it. The lead-bearing limestone of Galena has sufficient chert to produce beds of gravel a fourth as thick as the limestone system. The Erie limestone is particularly filled with chert, as may readily be seen wherever it is exposed. Along the west bank of the Neosho river for a few miles below Austin is a splendid place to make such observations. Chert nodules of many shapes and sizes are here to be seen in great abundance. They are uniformly filled with seams, which in position are entirely independent of the fissures in the inclosing limestone. When they weather out of the limestone they fall into many fragments, corresponding in size very well with the gravel near by. The middle system of the three carries the largest quantities of chert, as Bennett has described in chapter IV. The whole surface of the country where this system is exposed is almost completely covered with gravel, some of which on the prairies east of Portervale a few miles are large boulders measuring in extreme cases 3 feet or more across. It is a conservative estimate to place the amount of chert in this one system at a quantity sufficiently great to make a gravel bed fully 12 inches thick over the whole surface now covered by the limestone, provided it could be freed from the matrix all at once. The upper member of the Oread limestone likewise has large quantities of chert within it, and the surface gravel, as noted, is correspondingly great over areas from which the limestone has been eroded. Passing westward, the next limestone system particularly noted for the flint it carries is a heavy system first observed along the Cottonwood river—as shown in plate III—capping the hills about two miles west of Strong City. It lies about 150 feet above the Cottonwood Falls limestone, and constitutes a system reaching from 25 to 30 feet in thickness. Flint masses are remarkably abundant in the limestone, so much so that in different localities it constitutes from a fourth to a third of the entire mass. A quarry is opened at

this place and the rocks crushed for ballast along the Atchison, Topeka & Santa Fé railway, thousands of car-loads of material being used in this way. Above this about 200 feet another heavy limestone is found which likewise carries immense quantities of flint. It is quarried at Florence and portions of it crushed for ballast the same as at Strong City. To the north of the Cottonwood river the same two systems extend all the way to Junction City and probably much farther. Throughout the whole of this area the surface is everywhere covered with gravel deposits of varying amounts. Southward from the Cottonwood river area the two limestone systems extend into the Flint Hills region, and unmistakably have furnished the greater portion of the flint so abundant in that locality.

It may be stated that not a single limestone system of any considerable importance has been found in the whole of the Coal Measures which did not carry a perceptible amount of flint. Those just enumerated are the ones which have it in the greatest degree.

In the second place it has been observed that the gravel usually is most abundant in the vicinity of a limestone system rich in chert, or in places over which such limestone probably extended. The gravels about Oswego occupy space undoubtedly covered at one time by the Erie limestone; those so abundant about Cottonwood Falls lie under the earlier extension of the system just described, which carries so much chert. On the other hand, the area where the surface is most nearly barren of gravel are always areas farthest removed from chert-bearing limestones. Of these the Cherokee shales area in Cherokee and Crawford counties is the most prominent, for no other area equal in extent has been observed which is so entirely free from gravel.

In the third place, we found that many of the rounded surfaces possessed by the gravel are the original curved forms the cherts possessed while in their limestone hosts. This is particularly noticeable at Cottonwood Falls. Countless numbers of these have unmistakably such rounded forms. Some were found with traces of the limestone still adhering, others with the curved surfaces still possessing the rough character the chert surfaces have while in the limestone, and which in no particular resemble water-worn sur-

faces. The angular parts of the chert often have been worn little more than one would expect to observe on chert masses which had been subject to the weathering agents for long geological periods with such slight movements as might well be attributed to local causes.

It may well be argued, however, that ordinarily the gravels have been transported but a short distance if at all. Wherever they are found there is always an intimate mixture of the large and the small, sometimes with variations from half an inch to 10 or 12 inches in diameter. This alone is sufficient to show that they have never been subjected to the sorting power of water; for sand and gravel which have been transported by water are always more or less graded into relatively uniform-sized grains in any given locality.

It seems very probable, therefore, that in most instances the surface gravels of eastern Kansas have been derived from the native limestone systems, and that they are the direct results of the weathering of those limestones which, when dissolved and carried away by solvents, have left behind the less soluble chert. The chert boulders of such varied sizes and shapes fell into fragments on account of the numerous fissures everywhere prevalent, and the gravel was the result. As terrain after terrain yielded to the slow but sure processes of disintegration and destruction the insoluble chert formed residual products which gradually settled to the lowest level possible, which may have been the summit of a hill, or the bed of a river, or any intermediate position. Here and there the rolling down the hillside, the being moved by water in times of floods, the abrasive effects of moving soil and sand produced by wind or water, rounded the edges and blunted the sharp angles, in some places more than in others. Similarly the gravel has accumulated, now in broad, even layers, then in windrow-like masses formed by irregular surfaces and unequal amounts of the chert in the limestone. If there ever was a period during which Kansas was flooded by water from the melting glaciers such waters of course would assist in working over and arranging the gravel into beds. But it can hardly be argued that the gravel beds of themselves predicate the former existence of such water in Kansas territory.

This view is believed to be in harmony with the generally accepted

views of leading geologists regarding the origin of many other formations of similar character. Surface gravels are present in many different parts of the world. They cover the highest hilltops of our great mountain systems and fill the deepest valleys. Altitude seems to have no effect upon them. They were perplexing in the extreme until geologists began to look upon them as being only residual products left behind when the more perishable materials passed away.

CHAPTER XIV.

THE COAL MEASURE SOILS.* (Preliminary.)

BY ERASMUS HAWORTH.

General Principles. Kansas Soils.
Glacial Soils. Soil Fertilization.
Investigations Inaugurated by this Survey.

GENERAL PRINCIPLES.

A preliminary discussion of the Coal Measure soils is added to the body of the Report with the hope that the statement of a few fundamental principles of soil production, and consequently soil composition, may be of value, and at the same time serve as a guide for further observations.

Soils are formed from rocks, by both mechanical and chemical disintegration. The former alone is not sufficient, for it fails to render the essential components of the soil soluble. The latter rarely if ever occurs without being accompanied by the former, and perhaps could not occur to a considerable extent without being associated with it. We may select a rock sample which the chemist finds to contain all the elements present in the best of soils, excepting organic matter, and may grind it to a fine powder; but it is not a soil, for it will not sustain vegetation unless further changed. The plant can only use the mineral matters of the soil after they have been rendered soluble, and this can only be accomplished by chemical disintegration. This latter process is brought about in nature principally through the agencies of moisture and the atmosphere. If a mass of rock is kept in contact with the air, but

*This chapter deals principally with a statement of methods proposed for future examinations of soils, and the scientific basis upon which such methods depend. Little work has yet been done in soil examination.

perfectly dry, it will not decay or disintegrate chemically to any considerable extent. Likewise, if it be kept moist, but have all air excluded from it, chemical change will take place very slowly, if at all. But if the rock is kept constantly moist, and at the same time is continually bathed by the atmosphere, decay will progress at the maximum rate. Now the rain-waters passing through the air dissolve portions of it and carry the dissolved parts downwards until they are all consumed by uniting with rock constituents, which in turn are carried through processes of decay. It is those portions near the surface, therefore, that decay the most rapidly, and hence soils are produced at and near the surface rather than at greater depths.

The influence of decaying vegetation, also, is very great. Decaying plant or animal matter assists chemical action, so that when such is intimately mixed with soils it greatly accelerates chemical changes. But this furnishes more available food for the growing plants, which in turn supply a larger amount of organic matter to decay the following season. Thus the two processes mutually assist each other, and if neither is checked by artificial or natural means the depth and richness of the soil will continuously increase. But if the earthy matter is removed by drainage as fast as it is rendered soluble, as tends to be the case in hilly countries, or if the vegetation is removed as fast as grown, as is sometimes the case in certain lines of agriculture, depth and richness of the soil cannot be greatly increased. There is no good reason, therefore, why a soil should ever become exhausted. If the chemical decay can be made to keep pace with the carrying away of the products rendered soluble, a soil will remain as good as new so long as there is anything below to be decayed. It is a well-known fact that in many parts of the world the same piece of ground has been cultivated for more than a thousand years and is to-day as rich and productive as at any time in its history. We may impoverish a soil by taking away in any manner whatever the portions rendered soluble by chemical change more rapidly than new soluble compounds are produced, or we may enrich a soil by allowing it to retain a portion of the soluble parts while new ones are being formed. It is similar to

one's bank account. Anything which retards the drawing out, or which increases the rate of deposits, will increase the cash value of the deposit.

But by the processes mentioned above no soluble product can be produced in the soil the essential constituents of which were not originally in the rocks whose decay produced the soils. If rocks differ in their chemical properties soils produced from them will likewise differ in richness. If a given rock system does not contain the essential constituents of a good soil, no amount of decay of any kind can add them to the soil. The study of soils, therefore, becomes partially a study of the nature of the rocks which have produced them, and as such is strictly a geologic study. In nature we often find different rock systems placed one above another in such a way that on the high uplands the soil over a considerable area has been formed almost entirely from the topmost rock system, while along the bluffs and precipices the decayed products from two or more systems are falling to the valley below, adding a greater variety of materials, and hence increasing the possibilities for the production of a rich soil. In times of freshets and overflows the soils of valleys are often carried down stream many miles or even hundreds of miles by our large rivers and deposited along the banks and over the valley lands, thereby greatly increasing the possibility of mixing the proper constituents for a rich soil. These are the main conditions which cause the soils in "bottom" lands to be richer and better than the soils on uplands.

The depth of a soil also has much to do with its productiveness. This may be illustrated in the following manner: Place 10 pounds of good, rich soil in one box and 100 pounds of the same soil in a larger box. We will suppose that 1 per cent. of the soil is soluble. Plant seed of any kind in each box. When the crop has grown sufficiently to absorb a tenth of a pound from the small box it must cease growing, unless something can be done to give it more mineral food, while the crop in the large box can continue to grow ten times as long, or can grow ten times as fast. As our crops are grown on the farm they never exhaust the soluble mineral matter in a season. If the soil is shallow, however, they carry it close to exhaustion every season; but if it is 5 or 10 times as deep it will have such vastly

greater quantities of available plant-food that it will remain a rich soil much longer, and never will become exhausted if properly treated. The glacial soils of our northern states, and many other soils of similar depth, are usually spoken of as inexhaustible, and in fact they are if only properly treated. Many soils in America and other parts of the world are so new, that is, such small portions of the rocks have been decayed to form them, that they are very shallow, and consequently, like the soil in the small box, have their soluble material removed by cultivation so much more rapidly than new soluble products can be formed, that they soon become almost entirely impoverished.

GLACIAL SOILS.

In many parts of the world another agent has been instrumental in mingling the soils from different rocks and thereby increasing their possibilities for richness. I refer to the action of the glaciers during glacial times. It so happened that for long geologic ages certain portions of the American continent in the Great Lakes districts, and further north in Canada, were exposed to the weathering agents and suffered decay to unusually great depths. When the great masses of ice moved southward during the glacial period they scraped before them this loose mass and spread it out over the northern states, thereby giving them a coating of soil which was not formed by the decay of the rocks within their borders. Such soils, in general, are remarkably similar, even though they may be widely separated at present. They are similar not because they have all been transported by a mass of ice, but because they were originally formed from similar rock masses.

KANSAS SOILS.

For convenience we may refer to soils produced from rocks in the same vicinity where they now exist as *indigenous* soils, and to those which have been transported from other localities, such as the glacial soils, and many soils along our river valleys, as *exotic* soils. The Coal Measures of Kansas furnish examples of both kinds. The northeast part of the state, including nearly all the counties north of the Kansas river and east of the Blue, is princi-

pally covered with the exotic glacial soils, while the greater portion of the remainder of the Coal Measures is covered with indigenous soils. On the uplands near the Kansas river to the north the glacial soils are thin, and in some places entirely wanting. But to the northward they increase in thickness until in the northern tier of counties they usually are so deep that the stratified rocks of the country are rarely visible. Such soils are almost identical with the soils in northern Missouri, southern Iowa, and southeastern Nebraska. The general aspect of the country in the corners of these four states is remarkably similar, and, very naturally, the farmers have apparently accidently followed almost precisely the same course in agriculture and stock-raising. Visit the localities mentioned and one cannot tell by the surface appearances, nor by the crops and stock on the farms, which one of the four states one is in.

South of the Kansas river we have indigenous soils; that is, soils produced by the disintegration of the rocks underlying them. They are, therefore, almost entirely dependent for their chemical composition upon the character of the rocks from which they have been derived. In the preceding chapters of this Report it has been shown that the rocks are of three classes, limestones, sandstones, and shales, with the latter greatly predominating in amount. These three kinds of rocks are associated in such a manner, one above another, that the limestones form great shelves, sometimes 200 or 300 feet apart, with the sandstones and shales lying between them. The latter two often grade into each other, but the former rarely changes into the latter. All of these formations dip slightly to the west, or northwest, while the surface rises in that direction. The surface is therefore composed of a series of zones, or belts, approximating parallelism, trending north and south, or more exactly, a little northeast and southwest, each zone representing the soil produced from one shelf of rock, while its neighbors west and east equally represent zones of soil produced from the shelves first above and first below respectively.

A glance at the accompanying geologic map, and the various sections, will make this matter plain. In the southeast part of the state we have the heavy bed of the Cherokee shales. Their great thickness and the slight rise in the surface to the northwest combined cause

them to occupy a belt of surface over 20 miles wide, and reaching from a hundred miles or more in Missouri to an equal distance into the Indian Territory. Over this territory the soil is almost exclusively produced from the Cherokee shales, and all of its characters correspond. It is light in color, and very fine in texture, so that in dry weather it breaks up into an exceedingly fine dust along the roads and in the cultivated fields. Such soils are usually spoken of as "ashy" soils, and the name is excellently chosen, at least so far as color and texture are concerned. In places where the sandstone is abundant its disintegration has greatly affected the appearance of the soil by yielding so much sand to be mixed with it. The apparent effect, however, is much greater than the real; for the sand grains are practically insoluble, and therefore the available plant-food nearly all comes from the decomposed shale material mixed with the sand.

To the west of this zone we have a limestone area, the Oswego limestone, and a soil dependent upon a mixture of products from the limestone and the shales. As was shown in chapter X, while discussing the topography, here and all over the Coal Measure area, the limestone shelves are broken through in many places and deep valleys cut into the underlying shales, leaving hills, bluffs and mounds with the limestone still covering their summits. It is wonderful the influence the limestones have upon the soils. As one travels northwestward from the Cherokee shale belt one can tell almost to the rod, certainly to the half mile, when one comes in contact with a soil partially produced from a limestone. The color is changed from the ashy gray to a black, or to an iron-rusty red, usually the black. The texture is changed from the fine, dusty, to a coarser granular. In wet weather it does not seem to be so plastic and impervious to water, while in dry weather it is not usually so hard and cloddy.

It is quite evident, therefore, that the two soils are dissimilar in essential properties, and in their study should be kept separate. We may pass along either zone many miles in the direction of their trend, without finding any apparent change, while near the borders a mile or two in a transverse direction will make the change com-

plete. These two examples will illustrate the indigenous soils of the Coal Measure shales. In many places the limestone systems are thin and close together, so that their products of decay mingle freely with the soils produced from the shales over large areas. But wherever we have thick shale beds, as the Cherokee shales, the Pleasanton shales, the Lane shales, etc., we have the characteristic ashy gray soils.

From these considerations it will be readily seen that any examination or classification of our Kansas soils should be based upon geologic conditions and the geographic distribution of the different geologic formations which produce the different kinds of soils.

It may now be well to consider the origin and nature of the shales from which so large a proportion of our soils are derived, for such an understanding is essential to an intelligent knowledge of the soils. They have been formed under water, usually salt water, particularly the Kansas shales, as has already been shown in chapter IX, from the finer sediments—the mud—carried to the ocean from the dry-land areas. Along with the silt a considerable amount of sand was brought down, and was also deposited in broad, flat layers under the water. But as the sand was coarser and heavier than the silt it would not be carried as far oceanward as the latter. Hence there would be a partial separation of the two, each being deposited in part by itself, but in part with the other. The silt doubtless originally was a soil, or a portion of rock at least partially disintegrated into a soil. During the transportation all soluble products would be dissolved by the carrying waters, and therefore would not be deposited with the silt, or mud. So long as the shale material remained under the water it was deprived of the influence of the air, and therefore, chemical disintegration could not occur to produce more soluble matter. When in the course of time the movements of the earth again brought the shale-forming material above ocean water and left it in the position it now occupies it consisted of a mass of finely divided matter which was void of soluble compounds, and hence of available plant-food. But after it was lifted into dry land it would still have the air excluded, excepting those portions near the surface.

During all of this period whatever changes may have occurred

within the mass were formative, rather than destructive. They have been along the line of a rearrangement of the chemical constituents producing stable, insoluble compounds, rather than unstable, soluble ones. Recently many of the fresh shales have been carefully examined with the microscope. They have invariably been found to consist of well-crystallized particles which chemically seem to be very stable. But on account of the softness of the shales and the fineness of the particles they weather rapidly, producing masses of earth which mechanically are well disintegrated, but which chemically are relatively fresh. That is the character of large portions of the soils produced from shales. They are plastic, like clay, in fact are principally clay. Their plasticity makes them run together into compact masses. Water will not soak through them readily, and when they dry they become hard and cloddy. Such materials are usually called "hard-pan," or "gumbo," and invariably can be found all over the world where soils are largely produced from shales, or where the mechanical disintegration has greatly outstripped the chemical. One usually has to dig only from 8 to 12 inches in such soils to find the yellow clay, or hard-pan.

SOIL FERTILIZATION.

From the explanations given in the preceding pages, the reader has already anticipated that soil fertilization consists in increasing the amount of available plant-food within the soil, or the available soluble matter. This may be done in two ways: First, by the process nature originally uses in the formation of soils—that is, by the chemical disintegration of materials already present; and second, by the addition of one or more elements to the soil. If the agriculturist does either of these he is fertilizing his soil, enriching it, making it produce larger quantities and better qualities of plant tissue, of farm products. We will consider the two methods of fertilization separately, and in the order mentioned.

If the mass analysis of any soil shows that it has present, and in about the proper proportion, all the constituents desirable as plant-food, it will only be necessary to cause the chemical disintegration to keep pace with the sum total of the wastes of soluble matter in order to maintain the soil in the same degree of richness it originally

had; and should the rate of chemical decay surpass the rate of total loss of soluble matter, the soil will continuously grow richer. Starting with such a soil, there is no excuse for allowing it to become worn out or exhausted within a thousand years. We must increase the chemical decay and decrease the loss. Of the various possible methods of obtaining the former, proper cultivation is one of the best. Stirring the soil helps to bring the air in contact with it, and to make it most susceptible to the influences of the frosts of winter and the warm sunshine of spring and summer. The freezing in winter causes the whole surface to become open and porous, which in turn admits the air and the spring showers, all of which is very désirable because beneficial. Decaying organic matter also is an active agent in hastening chemical decay. The vegetable fiber will readily decay under atmospheric agencies, producing a great variety of chemical compounds, usually expressed under the one term "humus." Some of the compounds act chemically upon the little soil grains, producing new and soluble compounds from a portion or all of their constituents. If the organic matter is thoroughly mixed with the soil for several inches in depth it helps to make the soil loose and open, which as just stated, is a most effective method of producing chemical decay. Decaying organic matter, therefore, benefits the soil in many ways entirely outside of the addition of the nutritious material it furnishes. In a similar manner the growth of plant roots is a great benefit. The roots render the soil with which they are immediately in contact soluble. This power of plant roots is so great that they will even decompose solid rock. The deeper into the earth the plants send their roots the better service they perform, for thereby they carry this chemical disintegration much farther than otherwise would be possible; and when they finally die and decay the spaces they occupied are converted into innumerable little air-tubes which permit the relatively free circulation of air to depths which otherwise could not have been reached. This is the principal reason why the soils in our great forests are usually so rich. In their growth the mammoth trees have extracted vast quantities of mineral matter from the soil and have returned only a tithe of the same with their leaves which have annually fallen and decayed. Yet during this long period of their

preying upon the soil they have returned a tenfold equivalent by the influence their roots have had upon the depths below.

Another excellent method of assisting chemical decay is to treat the soil with some chemical which will decrease or destroy the plasticity of the clay contained in the soil and in the subsoil below; for in this way the soil is made more loose and porous, and therefore more susceptible to the atmospheric agencies already mentioned. Lime is an excellent material to be used in this way. Applied to any clay it weakens or totally destroys its plasticity, gives it that flocculent property which results in the formation of little grains, producing in the soil that granular property which is so constant a mark of a good soil. Lime is strongly recommended, then, as a most excellent material to add to any and all soils which are underlaid with a yellow clay, a hard-pan, gumbo, or what not, or to any soil which is not sufficiently porous to admit of water settling rapidly after a rain. It is recommended on account of its physical action, entirely regardless of whether the soil needs more lime for plant-food or not. As limestone is so abundant in Kansas it can be obtained almost everywhere at a nominal cost, and in many instances can be spread on the fields at the rate of from 50 to 75 bushels to the acre with no outlay of money whatever. The ordinary limestone will do excellently for furnishing such lime. It may be so impure that it will not make marketable lime, but most likely the impurities themselves will be good for the soil; certainly they can do no harm. In the famous blue-grass region of Kentucky the rich soil largely owes its character, according to Professor Shaler,* to the small amount of phosphoric acid an impure limestone of the country contains. Could such a limestone be burned and spread on our Kansas soils there can be no question but that the soil would be benefited in two ways: one by the lime, and one by its impurities. It is entirely possible that we have similar limestones in our state.

The second mode of fertilization of soils is entirely different in principle from the one just described. It assumes, to begin with, that the growth of vegetation desired cannot be accomplished without the addition of one or more elements which the soil does not

*Twelfth An. Rep. Director U. S. Geol. Surv., article on "Soils."

possess, or which it contains in too limited quantities. Before applying any such materials the rational mode of procedure would be to have mass analyses made of the soils in question to determine what materials it is necessary to have added from outside sources. If one or more essential plant foodstuffs is present in the soil, but not available because not soluble, economy would necessitate such treatment as would render them soluble. But with the soils produced from rocks, as has been shown, and the different rock formations being spread over such large parts of the surface, as has been shown to be the case for eastern Kansas, it is quite possible, indeed probable, that a soil produced from one particular rock mass may be largely or wholly destitute of one or more elements desirable for plant-food. When this has been determined by the mass analysis of the soil, it will be an easy matter to add the particular constituent necessary.

In the ordinary course of agriculture large quantities of vegetable matter are removed from the farm every year, and a corresponding amount of soluble matter, which is now stored up within the plant, is taken from the soil. The natural drainage of the soil also takes away a considerable amount, and in hilly countries this becomes a very serious matter. Whenever such removal exceeds the rate of chemical decay the soil is correspondingly impoverished, and unless something can be done in some way to check the loss, or to accelerate the decay, it is only a question of time when the soil becomes almost entirely unproductive. There may be, therefore, two fundamental reasons why outside materials should be added to any given soil: one from its original absence; and the other from its artificial absence. In such cases the direct addition to the soil of such plant-foods is desirable. They may be obtained from the commercial fertilizers, or from the common barn-yard manures.

Throughout the above discussion no reference has been made to any plant-food which is essentially organic in its nature, yet soils of whatever character are practically worthless unless soluble nitrates are present in considerable quantity. It is now very well understood that these nitrates can be gathered into the soil through the agencies of the leguminous plants, such as the clovers, beans, peas, etc. The necessary treatment to obtain the nitrogenous ma-

terials, therefore, is to add nitrogenous-bearing organic matter to the soil, or to grow some of the crops just mentioned, so that the roots may decay within the soil. Clover is the most common plant grown for this purpose, and while it is gathering from the air a supply of nitrogen for the soil its roots are also actively engaged in the decomposition of the soil materials. Clover is, therefore, aside from its value as a crop, one of the most beneficial plants that can be raised on a poor soil. But in some localities of the state clover being raised on a poor soil.

But in some localities of the state clover does not grow advantageously. This is particularly true in soils produced from the great shale beds, especially from the Cherokee shales. If one travels across the country from northwest to the southeast, it will be noticed that clover-fields are abundant in all localities where limestone soils exist. But no sooner are the light, ashy soils of the Cherokee shales reached than the clover-fields disappear. The boundary between the localities of clover-fields and no clover-fields is almost as sharp as that between the two kinds of soils. Inquiry from scores of farmers on both sides the line elicited the fact that for some reason unknown to them the clover did well on one kind of soil and could scarcely be made to grow at all on the other. Inasmuch as practically we have the same kind of farmers on both sides of the line and the same meteorological conditions, we are forced to conclude that the cause for this great difference is principally due to the difference in the soils. In such cases something must be done in some way to make the soil produced from shales capable of sustaining heavy growths of clover before any beneficial results can be obtained by clover-growing. What treatment will be necessary is one of the problems this Survey will attempt to solve.

Artificial fertilizers are both beneficial and dangerous when placed on soils. They are beneficial because, when intelligently applied, they greatly increase the productive powers of a soil. They are dangerous on account of the great possibilities for them to exercise an influence on the soil, either chemical or physical, which will interfere with the natural reproductive power soils normally possess, and thereby soon deprive the growing crops of

essential food supplies. If the fertilizer, or any solvent or vehicle it contains, should act in this way it might be used with success for a short time, but sooner or later with opposite results. It is reliably reported that many of the farms in the older parts of America which have been treated with phosphate and potash fertilizers for years are to-day inferior in productive capacity to others in the same locality which have not been fertilized so extensively. Any fertilizer which directly or indirectly increases the plasticity of the clay within the soil or subsoil greatly retards the normal chemical decay, and thus has an injurious effect on the soil. On the other hand, any fertilizer, artificial or natural, which decreases the plasticity of the clay will to that degree be beneficial independent of the supply of food matter.

INVESTIGATIONS INAUGURATED BY THIS SURVEY.

In beginning a series of investigations on the Kansas soils this Survey has taken up two lines of work: one, the getting of samples for laboratory examinations, and the other the application of various fertilizers to different kinds of soils. In the gathering of soil samples great care is taken to select localities that will furnish good representatives of the different kinds of soils viewed from the geologic standpoint. The soils produced from shales, from limestone, from sandstone, and the mixtures of two or more kinds, are gathered separately. This kind of work cannot progress far until the stratigraphic geology is pretty well worked up, and therefore must be largely deferred for some time.

The laboratory investigations will be of two general classes, physical and chemical. Recent researches in America and Europe have emphasized the importance of a proper physical condition of soil in order that the best results may be obtained by cultivation. It is quite possible to have two soils practically identical chemically, but different physically, and with reference to productiveness. The examination of the physical properties of soils will therefore be made an important branch of the laboratory investigations. The chemical work will be done by the chemical department, and will consist of ultimate and proximate analyses, and a determination of the amount and kinds of soluble matter. In this way it is hoped

to be able to determine the presence or absence of the most important plant foodstuffs, so that an intelligent idea can be had of the materials necessary to be added to the different soils in the way of fertilizers.

The experiments on the effect of different fertilizers on different soils and for different crops are intended to supplement the laboratory investigations. The plan of operation is to supply materials to reliable farmers in different parts of the country, chosen with reference to the different kinds of soils on their farms, and the different kinds of crops raised. It is quite probable that both lime and gypsum, or land plaster, will be quite beneficial to all of our soils produced from shales. Such materials will be extensively tried on a great variety of soils, and for different kinds of crops. Animal fertilizers from the large packing-houses will also be tried, as will salt and other marketable products. Associated with some of the extensive salt beds in Europe, particularly at Stassfurt, are vast deposits of potash salts. These are highly prized the world over as fertilizers for soils poor in potash. Most likely we shall find that our soils are generally deficient in this element. It will therefore be of interest to every one to know whether our Kansas salt beds will yield any of this material. Thus far none has been produced, but if it be found every one will be benefited.

CHAPTER XV.

A PRELIMINARY CATALOGUE OF THE INVERTEBRATE PALEONTOLOGY OF THE CARBONIFEROUS OF KANSAS. (Preliminary.)

BY JOHN BENNETT.

In this chapter is given a preliminary synopsis of the invertebrate fauna of the Mississippian, the Coal Measures, and the Permian formations in Kansas, arranged first with reference to their biologic aspect, and second according to counties. The classification adopted is mainly that of Von Zittel, and the arrangement on the page is made as convenient as could well be done. Few species have been included which have not been inspected by the writer, but some have been copied from the writings of Professor Prosser and from a manuscript furnished by Mr. Beede, of Topeka. Those copied from Prosser are followed by the letter (P), and those copied from Beede by the letter (B). For many reasons this catalogue is deficient, and therefore it should be looked upon only as preliminary. It is published here to serve as a beginning, with a hope that it may be perfected at some future time.

The animal kingdom may be divided into seven subkingdoms, or branches, as follows:

I, Protozoa.
II, Cœlenterata.
III, Echinodermata.
IV, Vermes.
V, Mollusca.
VI, Arthropoda.
VII, Vertebrata.

Of these the following have been observed:

Branch I.—PROTOZOA.

CLASS RHIZOPODA.

One genus and three species.

Fusulina Fischer, 1857, Oryct. du Gouv. de Moscou.
cylendrica Fischer, 1837, Oryct. du Gouv. de Moscou.
robusta Meek, 1864, Pal. California, vol. 1.
ventricosa Meek and Hayden, 1864, Pal. Upper Mo.

Branch II.—CŒLENTERATA.

CLASS ANTHOZOA.

Eight genera and eight species.

Axophyllum Edwards and Haime, 1850, Brit. Pal. Foss.
rudis White and St. John, 1868, Trans. Chi. Acad. Sci.
Campophyllum Edwards and Haime, 1850, Brit. Foss. Corals.
torquium Owen, 1852, Geol. Rep. Iowa and Minn.
Cyathaxonia Michelin, 1846, Icon. Zooph.
distorta Worthen, 1875, Geol. Sur. Ill., vol. 6.
Cyathophyllum Goldfuss, 1826, Petref. Germ.
——— sp.
Lophophyllum Edwards and Haime, 1850, Brit. Foss. Corals.
proliforum McChesney, 1860, New Pal. Foss.
Michelinia DeKoninck, 1842, Desc. des Anim. Foss. Belg.
eugeneæ White (Ind. 1883), Geol. and Nat. Hist., 13th Report.
Syringopora Goldfuss, 1826, Germ. Petref.
multattenuata McChesney, 1860, New Pal. Foss.
Zaphrentis Rafinesque, 1820, Ann. des Sci. Phys. Brux., vol. 5.
——— sp.

Branch III.—ECHINODERMATA.

Order CRINOIDEA.

Eleven genera and sixteen species.

Agassizocrinus Troost, 1850, Ms. of Monograph Crinoidea.
carbonarius Worthen, 1873, Geol. Sur. Ill., vol. 5.
Catillocrinus Troost, 1850, Cat. Foss. described by Shumard, 1866, Trans. St. Louis Acad. Sci.
wachsmuthi Meek and Worthen, 1866, Proc. Acad. Nat. Sci. Phil.
Cyathocrinus Miller, 1821, Nat. Hist. Crinoidea.
sangamonensis Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
Erisocrinus Meek and Worthen, 1865, Am. Jour. Sci., vol. 89.
typus Meek and Worthen, 1865, Am. Jour. Sci., vol. 89.
Eupachycrinus Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
craigi Worthen, 1875, Geol. Sur. Ill., vol. 6.
tuberculatus Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
Graphiocrinus De Koninck and Le Hon, 1854, Rech. Crin. Carb. Belg.
——— sp.

Pentremites Say, 1820, Am. Jour. Sci., vol. 2.
conoideus Hall, 1856, Trans. Alb. Inst., vol. 4.
godoni DeFrance, 1818, Dict. Sci. Nat.
Platycrinus Miller, 1821, Nat. Hist. Crinoidea.
——— sp.
Poteriocrinus Miller, 1821, Nat. Hist. Crinoidea.
hardinensis Worthen, 1873, Geol. Surv. Ill., vol. 5.
Scaphiocrinus ? (Poteriocrinus) Hall, 1858, Geol. Rep. Iowa.
hemisphericus Shumard, 1858, Trans. St. Louis Acad. Sci.
Zeacrinus Troost, 1850, Catal. Foss. 1850, and described by Hall, 1858, Geol. Iowa.
acanthophorus Meek and Worthen, 1870, Proc. Acad. Nat. Sci. Phil.
discus Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
mucrospinus McChesney, 1859, New Pal. Foss.
typus.

Order ECHINODERMATA.

One genus and four species.

Archæocidaris McCoy, 1844, Carb. Foss. Ireland.
mucronatus Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
norwoodi Hall, 1858, Geol. Rep. Iowa.
shumardiana Hall, 1858, Geol. Rep. Iowa.
triserrata Meek, 1872, Pal. E. Neb.

Branch IV.—VERMES.

Class ANNELIDA.

Two genera and two species.

Serpula Linnæus, 1758, (Spirorbis of Lamarck 1801) Syst. Nat., 10th ed.
incita.
Spirorbis Lamarck, 1801, Syst. An. sans. Vert.
carbonarius Dawson, 1845, Quar. Jour. Geol. Soc., vol. 1.

Branch V.—MOLLUSCA.

Class Bryozoa, sixteen genera and twenty-two species.
Class Brachiopoda, seventeen genera and sixty species.
Class Lamellibranchiata, thirty-five genera and eighty-five species.
Class Gasteropoda, seventeen genera and fifty-nine species.
Class Cephalopoda, four genera and eighteen species.

Class BRYOZOA.

Archimedes La Sueur, 1842, Am. Jour. Sci., vol. 43.
——— sp.
Batostomella (B).
intersticta Ulrich.
Chætetes Fischer, 1837, Oryct. du Gouv. Moscou.
carbonarius Worthen, 1875, Geol. Surv. Ill., vol. 6.
milleporaceus Troost.
Cyclopora ? ? (B).
——— sp.

Fenestella Lonsdale, 1839, Murch. Sil. Syst.
compressa Ulrich (B).
limitaris ? Ulrich (B).
modesta ? Ulrich (B).
shumardi Prout, 1858, Trans. St. Louis Acad. Sci., vol. 1.
sevillensis ? Ulrich (B).
Fistulipora McCoy, 1849, Ann. & Mag. Nat. Hist., 2d series, vol. 3.
nodulifera Meek, 1872, Pal. E. Neb.
Glauconome Goldfuss, 1826, Germ. Petref.
nereidis White, 1874, Rep. Invert. Foss.
Lyropora ? (B) Hall, 1857, Proc. Am. Assoc. Ad. Sci., vol. 10.
——— sp.
Polypora McCoy, 1845, Carb. Foss. Ireland.
submarginata Meek, 1872, Pal. E. Neb.
Ptilodictya ? Lonsdale, 1839, Murch. Sil. Syst.
triangulata.
Rhombopora Meek, 1872, Pal. E. Neb.
lepidodendroides Meek, 1872, Pal. E. Neb.
Septopora ? (B) Prout, 1859, Trans. St. Louis Acad. Sci.
——— sp.
Stenopora (B) Lonsdale, 1845, Geol. Russ. and Ural Mts., vol. 1.
carbonaria Ulrich.
carbonaria var. *confuta* Ulrich.
Stictopora Hall, 1847, Pal. N. Y., vol. 1.
——— sp.
Streblotrypa (B).
nickelsi Ulrich.
Synocladia King, 1849, Trans. Geol. Soc. Lond., 2d series, vol. 3.
biserialis Swallow, 1858, Trans. St. Louis Acad. Sci.

CLASS BRACHIOPODA.

SPIRIFERIDÆ.

Athyris McCoy, 1844, Carb. Foss. Ireland.
lamellosa Leveille, 1835, Mem. Geol. Soc. France.
sublamellosa Hall, 1858, Geol. Rep. Iowa.
subquadrata Hall, 1858, Geol. Rep. Iowa.
subtilita Hall, 1852, Stansbury's Exped. to Great Salt Lake.
trinucleus Hall, 1882, Whitfield Bulletin 3, Am. Mus. Nat. Hist.

PRODUCTIDÆ.

Chonetes Fischer, 1837, Oryct. du Gouv. de Moscou.
glabra Hall, 1857, 10th Reg. Rept.
granulifera Owen, 1852, Geol. Rept. Wis., Iowa, and Minn.
mesoloba Norwood and Pratten, 1854, Jour. Acad. Nat. Sci. Phil., vol. 3.
millepunctata Meek and Worthen, 1870, Proc. Acad. Nat. Sci. Phil.
parva Shumard, 1855, Geol. Rep. Mo.
smithi Norwood and Pratten, 1854, Jour. Acad. Nat. Sci. Phil., vol. 3.
verneuiliana Norwood and Pratten, 1854, Jour. Acad. Nat. Sci. Phil., vol 3.

CRANIADÆ.

Crania Retzius, 1781, Schriften der Berliner Gesellschaft Naturforschende Freund.
——— sp.

STROPHOMINIDÆ.

Derbya* (M and H) H and C ?
bennetti Hall and Clarke, 1892, Geol. Surv. State N. Y. Pal., Pal. Brac., vol. 8, part 1.
broadheadi Hall and Clarke, 1892, Geol. Surv. State N. Y. Pal., Pal. Brac., vol. 8, part 1.

DISCINIDÆ.

Discina Lamarck, 1819, Hist. Nat. Anim. sans Vert.
convexa ? (B) Shumard, 1858, Trans. St. Louis Acad. Sci.
nitida Phillips, 1836, Geol. of York.
tennilineatus.

LINGULIDÆ.

Lingula Benguiere, 1792, Encyc. Meth.
carbonaria Shumard, 1858, Trans. St. Louis Acad. Sci.
melie ? Hall, 1867, Pal. N. Y., vol. 4.
mytiloides Sowerby, 1812, Min. Conch. Tab. 19.
scotica Davidson, 1860, Monogr. Scot. Carb. Brach.
umbonata (B) Cox, 1857, Geol. Surv. Ky., vol. 3.

STROPHOMENIDÆ.

Meekella White and St. John, 1868, Trans. Chi. Acad. Sci.
striato-costata Cox, 1857, Geol. Surv. Ky., vol. 3.

DISCINIDÆ.

Orbiculoidea d'Orbigny.
——— sp.

STROPHOMINIDÆ.

Orthis Dalman, 1827, Kougl. Vet. Acad. Handl.
carbonaria Swallow, 1858 (syn. for *pecosi* of Marcou, 18[illegible]3), Geol. N. Amer.
keokuk Hall, 1858, Geol. Rep. Iowa.
robusta Hall, 1858, Geol. Rep. Iowa.
Orthisina d'Orbigny, 1849.
schumardiana Swallow, 1858, Trans. St. Louis Acad. Sci.

PRODUCTIDÆ.

Productus Sowerby, 1814, Min. Conch., vol. 1.
altonensis Norwood and Pratten, 1854, Jour. Acad. Nat. Sci. Phil., 2d series, vol. 3.
americanus Swallow, 1863, Trans. St. Louis Acad. Sci.
cora d'Orbigny, 1842, Geol. Voy. Amer.
costatus Sowerby, 1827, Min. Conch., vol. 6.
longispinus Sowerby, 1814, Min. Conch., vol. 1.
magnus Meek and Worthen, 1861, Proc. Acad. Nat. Sci. Phil.
nebrascensis Owen, 1852, Geol. Rep. Wis., Iowa and Minn.
norwoodi Swallow, 1858, Trans. St. Louis Acad. Sci.

*Syn for *Streptorhynchus.*

Productus Sowerby, 1814, Min. Conch., vol. 1.
pertenuis Meek, 1872, Pal. E. Neb.
prattenianus Norwood, 1854, Jour. Acad. Nat. Sci. Phil.
punctatus Martin, 1809, Petrif. Derb.
semireticulatus Martin, 1809, Petrif. Derb.
symmetricus McChesney, 1860, Desc. New Pal. Foss.
tenuicostatus Hall, 1858, Geol. Rep. Iowa.
wortheni Hall, 1858, Geol. Rep. Iowa.

SPIRIFERIDÆ.

Retzia * King, 1850, Monograph of Permian Foss.
mormoni Marcou, 1858, Geol. N. Am.
vera Hall, 1858, Geol. Rep. Iowa.

RHYNCHONELLIDÆ.

Rhynchonella Fischer, 1809, Mem. Soc. Imp. Mosc.
metallica (B) White, 1874, Rep. Invert. Foss.
uta Marcou, 1858, Geol. N. Amer.

SPIRIFERIDÆ.

Spirifer Sowerby, 1815, Min. Conch., vol. 2.
camerata Morton, 1836, Am. Jour. Sci., vol. 29.
festigata Meek and Worthen, 1870, Proc. Acad. Nat. Sci. Phil.
keokuk Hall, 1858, Geol. Rep. Iowa.
lineata Martin, 1809, Petrif. Derb.
plano-convexa Shumard, 1855, Geol. Rep. Mo.
rostellata Hall, 1858, Geol. Rep. Iowa.
suborbicularis Hall, 1858, Geol. Rep. Iowa.
Spiriferina d'Orbigny, 1847, Consid. Zool. et Geol. Sur. les Brachiopodes comptes rendus des Sciences de l'Academie des Sciences.
kentuckiensis Shumard, 1855, Geol. Rep. Mo.

STROPHOMINIDÆ.

Streptorhynchus † (Hemipronites) King, 1850, Monograph of Permian Foss.
crassus Meek and Hayden, 1858, Proc. Acad. Nat. Sci. Phil.
crenistriatus Phillips, 1836, Geol. York., vol. 2.

STROPHOMINIDÆ.

Syntrialasma Meek and Worthen, 1865, Proc. Acad. Nat. Sci.
hemiplicatum Hall, 1852, Stansbury's Exped. to Great Salt Lake.

TEREBRATULIDÆ.

Terebratula Llhwyd, 1696, Lith. Brit. Ichn.
bovidens Mortin, 1836, Am. Jour. Sci., vol. 29.

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* Hall and Clarke propose Hustedia.
† Syn. for *Derbya*.

CLASS LAMELLIBRANCHIATA.

ARCADÆ.

Allorisma King, 1844, Ann. Mag. Nat. Hist., vol. 14.
antiqua Swallow, 1863, Trans. St. Louis Acad. Sci.
costata Meek and Worthen, 1869, Proc. Acad. Nat. Sci. Phil.
geinitzia (B) Meek, 1867, Amer. Jour. Sci., vol. 44.
granosa Shumard, 1858, Trans. St. Louis Acad. Sci.
marionensis White, 1876, Proc. Acad. Nat. Sci. Phil.
pleuropistha Meek, 1871, Proc. Acad. Nat. Sci. Phil.
reflexa Meek, 1872, Pal. E. Neb.
regularis ———
striata ———
subcuneata Meek and Hayden, 1858, Proc. Acad. Nat. Sci. Phil.

ASTARTIDÆ.

Astarte Sowerby, 1818, Minn. Conch., vol. 2.
——— sp.
Astartella Hall, 1858, Geol. Rep. Iowa.
concentrica McChesney, 1860, Descr. New Pal. Foss.
gurleyi ———
vera Hall, 1858, Geol. Rep. Iowa.

AVICULIDÆ.

Avicula Klein, 1753, Ostrac.
longa Geinitz, 1866, Carb. und Dyas in Neb.

PECTENIDÆ.

Aviculopecten McCoy, 1851, Ann. Mag. Nat. Hist., 2d series, vol. 7.
americana.
carboniferus Stevens, 1858, Am. Jour. Sci. and Arts.
constans.
coryanus White, 1874, Rep. Invert. Foss.
coxanus Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
hertzeri Meek, 1875, Ohio Pal., vol. 2.
maccoyi Meek and Hayden, 1865, Pal. Up. Mo.
occidentalis Shumard, 1855, Geol. Rep. Mo.
rectilaterarius Cox, 1857, Geol. Sur. Ky., vol. 3.
whitei ? Meek, 1872, Pal. E. Neb. (B).

PINNIDÆ.

Aviculopinna Meek, 1867, Am. Jour. Sci., vol. 44.
americana Meek, 1867, Am. Jour. Sci., vol. 44.

AVICULIDÆ.

Bakevellia King, 1849, Perm. Foss.
parva Meek and Hayden, 1858, Trans. Alb. Inst., vol. 4.

PHOLADOMYIDÆ.

Cardiomorpha De Koninck, 1844, Desc. Anim. Foss. Carb. Belg.
missouriensis Shumard, 1858, Trans. St. Louis Acad. Sci.

PRASINIDÆ.

Chænocardia Meek and Woethen, 1869, Proc. Acad. Nat. Sci. Phil.
ovata Meek and Worthen, 1869, Proc. Acad. Nat. Sci. Phil.

PHOLADOMYIDÆ.

Chænomya Meek, 1864, Pal. of Up. Mo.
leavenworthensis Meek and Hayden, 1858, Proc. Acad. Nat. Sci. Phil.
maria.

CARDIADÆ.

Conocardium Bronn, 1835, Leth. Geol.
obliquum Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.

CYPRINIDÆ.

Cypricardella Hall, 1858, Trans. Alb. Inst., vol. 4.
oblonga Hall, 1858, Trans. Alb. Inst., vol. 4.
Cypricardinia ? Hall, 1858, Pal. N. Y., vol. 3.
carbonaria Meek, 1871, Proc. Acad. Nat. Sci. Phil.

PHOLADOMYIDÆ.

Edmondia De Koninck, 1844, Desc. Anim. Foss. Carb. Belg.
aspinwallensis Meek, 1871, Hayden's Rep. Sur. Wyoming.
glabra Meek, 1872, Pal. E. Neb.
nebrascensis Geinitz, 1866, Carb. und Dyas in Neb.
ovata.
reflexa Meek, 1872, Pal. E. Neb.
subplana.
subtruncata Meek, 1872, Pal. E. Neb.

PECTENIDÆ.

Entolium Meek, 1864, Cal. Geol. Sur., vol. 2.
avicula Swallow, 1858, Trans. St. Louis Acad. Sci.

LIMIDÆ.

Lima Brugueire, 1791, Encycl. Meth. and Deshayes, 1824; Descrip. de Coquilles fossils des environs de Paris.
retifera Shumard, 1858, Trans. St. Louis Acad. Sci.

ARCADÆ.

Marcrodon Lycett, 1845, Murch. Geol. Chelt.
carbonarius Cox, 1857, Geol. Surv. Ky., vol. 3.
obsoletus Meek, 1871, Reg. Rep. University W. Va.
tenuistriata Meek and Worthen, 1867, Proc. Acad. Nat. Sci.

MYTILIDÆ.

Modiola Lamarck, 1801, Syst. An. sans Vert.
subeliptica.

AVICULIDÆ.

Monopteria Meek and Worthen, 1866, Proc. Chi. Acad. Nat. Sci.
gibbosa Meek and Worthen, 1866, Proc. Chi. Acad. Nat. Sci.
longispina Cox, 1857, Geol. Surv. Ky., vol. 3.
marian White, 1874, Rep. Invert. Foss.
Monotis Bronn, 1824, System Urwelthicher Konchylien.
gregaria Meek and Worthen, 1870, Proc. Acad. Nat. Sci. Phil.

MYTILIDÆ.

Myalina De Koninck, 1844, Desc. Amin. Foss. Carb. Belg.
kansasensis Shumard, 1858, Trans. St. Louis Acad. Sci.
perattenuata Meek and Hayden, 1862, Trans. Alb. Inst., vol. 4.
recurvirostris Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
squamosa Sowerby, 1827, Trans. Geol. Soc. Lond., 2d series, vol. 3.
subquadrata Shumard, 1855, Geol. Rep. Mo.
swallovi McChesney, 1860, New Pal. Foss.

NUCULIDÆ.

Nucula Lamarck, 1815. Hist. Nat. des An. sans Vert.
parva McChesney, 1860, New Pal. Foss.
ventricosa Hall, 1858, Geol. Surv. Iowa.
Nuculana Link, 1807, Rost. Samml., vol. 3.
bellistriata Stevens, 1859, Am. Jour. Sci., vol. 25.
bellistriata var. *attenuata* Meek, 1872, Pal. E. Neb.

PINNIDÆ.

Pinna Linnæus, 1758, Syst. Nat. 10th ed.
peracuta Shumard, 1858, Trans. St. Louis Acad. Sci.
subspatulata Worthen, 1875, Geol. Surv. Ill., vol. 6.

OSTREIDÆ.

Placunopsis Morris and Lycett, 1853, Monogr. Foss. Great Oolite (B).
carbonaria Meek and Worthen, 1866, Proc. Chi. Acad. Sci., vol. 1.

ASTARTIDÆ.

Pleurophorus King, 1844, Ann. Mag. Nat. Hist., vol. 14.
angulatus Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
oblongus Meek, 1872, Pal. E. Neb.
occidentalis Meek and Hayden, 1862, Trans. Alb. Inst., vol. 4.
subcostatus Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
subcuneatus Meek and Hayden, 1858, Trans. Alb. Inst., vol. 4.
tropidophorus Meek, 1875, Ohio Pal., vol. 2.

AVICULIDÆ.

Posidonomya Bronn, 1837, Leth. Geogn.
fracta Meek, 1875, Ohio Pal., vol. 2.

PHOLADOMYIDÆ.

Prothyris Meek, 1869, Proc. Acad. Nat. Sci. Phil.
elegans Meek, 1871, Am. Jour. Conch., vol. 7.

AVICULIDÆ.

Pseudomonotis Byrich, 1862, Zeit. der Deutsch., Geol. Gesselsch., vol. 14.
hawni var. *ovata* Meek and Hayden, 1865, Pal. Up. Mo.

PHOLADOMYIDÆ.

Sanguinolites McCoy, 1844, Synop. Carb. Foss. Ireland.
obliquus Meek, 1871, Proc. Acad. Nat. Sci. Phil.

TRIGONIDÆ.

Schizodus King, 1844, Ann. Mag. Nat. Hist., vol. 14.
curtus Meek and Worthen, 1866, Proc. Chi. Acad. Sci.
curtiforme Meek and Worthen, 1866, Pro. Chi. Acad. Sci.
wheeleri Swallow, 1862, Trans. St. Louis Acad. Sci.
——— sp.

SOLEMYIDÆ.

Solenomya Lamarck, 1818, Hist. Nat. Anim. sans Vert., vol. 5.
radiata Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
rhomboyda ———

SOLENIDÆ.

Solenopsis McCoy, 1844, Carb. Foss. Ireland.
solenoides Geinitz, 1866, Carb. und Dyas in Neb.

PECTENIDÆ.

Streblopteria McCoy, 1851, Ann. Mag. Nat. Hist., 2d series, vol. 1.
——— sp.

NUCULIDÆ.

Yoldia Muller, 1842, Kroyer's Nat. Tid.
subscitula Meek and Hayden, 1858, Trans. Alb. Inst., vol. 4.
——— sp.

CLASS GASTEROPODA.

PYRAMIDELLIDÆ.

Aclis Loven.
——— sp.

BELLEROPHONTIDÆ.

Bellerophon Montfort, 1808, Conch. Syst., vol. 1.
bellus Keys.
carbonarius Cox, 1857, Geol. Rep. Ky., vol. 3.
crassus Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
marcouanus Geinitz, 1866, Carb. und Dyas in Neb.
montfortanus Norwood and Pratten, 1855, Jour. Acad. Nat. Sci. Phil.
percarinatus Conrad, 1842, Jour. Acad. Nat. Sci. Phil.
stevensanus McChesney, 1860, Desc. New Pal. Foss.
textilliformis ———
tricarinatus Shumard, 1858, Trans. St. Louis Acad. Sci.

HELICIDÆ.

Dawsonella Bradley, 1874, Am. Jour. Sci., 3d series, vol. 7.
meeki Bradley, 1872, Am. Jour. Sci., 3d series, vol. 4.

SOLENOCHONCHÆ.

Dentalium Linnæus, 1740, Syst. Nat., 2d ed.
meekanum Geinitz, 1866, Carb. und Dyas in Neb.

SOLARIIDÆ.

Euomphalus Sowerby, 1814, Minn. Conch., vol. 1.
rugosus Hall, 1858, Geol. Rep. Iowa.

PYRAMIDELLIDÆ.

Loxonema Phillips, 1841, Pal. Foss.
rugosum Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
Macrocheilus Phillips, 1841, Pal. Foss.
angulifera White, 1874, Rep. Invert. Foss.
intercalaris Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
medialis Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
paludenæformis ? Hall, 1858, Geol. Rep. Iowa.
primigenius Conrad, 1835, Trans. Geol. Soc. Pa., vol. 1.
ventricosus (B) Hall, 1858, Geol. Rep. Iowa.

PLEUROTOMARIDÆ.

Murchsonia D'Archaic and Verneuil, 1841, Bull. Soc. Geol. Fr., vol. 12.
——— sp.

NATACIDÆ.

Naticopsis McCoy, 1844, Synop. Carb. Foss. Ireland.
altonensis McChesney, 1865, Desc. New Pal. Foss.
gigantia Hall, 1873, 23d Reg. Rep. N. Y.
monolifera.
nana Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
ventricosa Norwood and Pratten, 1855, Jour. Acad. Nat. Sci. Phil.
wheeleri Swallow, 1860, Trans. St. Louis Acad. Sci.

CAPULIDÆ.

Platyceras Conrad, 1840, Ann. Rep. N. Y.
equilateralis Hall, 1860, supp. to vol. 1, pt. 2d, Iowa Rep.
nebranscense Meek, 1872, Pal. E. Neb.

PLEUROTOMARIDÆ.

Pleurotomaria De France, 1826, Dict. Sci. Nat., 41.
bonharborensis Cox, 1857, Geol. Surv. Ky., vol. 3.
broadheadi.
carbonaria Norwood and Pratten, 1855, Jour. Acad. Nat. Sci. Phil., 2d series, vol. 3.
coniformis.
coxana Meek and Worthen, 1866, Proc. Acad. Nat. Sci. Phil.
depressa Cox, 1857 (preoccupied by others), Geol. Surv. Ky., vol. 3.
grayvillensis Norwood and Pratten, 1855, Jour. Acad. Nat. Sci. Phil. 2d series, vol. 3.
haydenana Geinitz, 1866, Carb. und Dyas in Neb.
illinoiensis Meek (B).
inornata Meek, 1872, Pal. E. Neb.
marcouana Geinitz, 1866, Carb. und Dyas in Neb.
newportensis ?
perhumerosa Meek, 1872, Pal. E. Neb.
speciosa Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
sphærulata Conrad, 1842, Jour. Acad. Nat. Sci. Phil., vol. 8.
subdecussata Geinitz, 1866, Carb und Dyas in Neb.
subscalaris Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.

Pleurotomaria De France, 1826, Dict. Sci. Nat., 41.
tabulata Conrad, 1835, Trans. Geol. Soc. Pa., vol. 1.
tumida Meek and Worthen, 1860, Pro. Acad. Nat. Sci. Phil.
turbiniformis Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
valvatiformis Meek and Worthen, 1866, Proc. Acad. Nat. Sci. Phil.

PYRAMIDELLIDÆ.

Polyphemopsis (Subulites Conrad) Portlock, 1843, Geol. Londonderry.
inornata Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
nitidula Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.

HELICIDÆ.

Pupa Humphrey, 1797, Museum Calonnianum.
vitusta Dawson, 1860, Quar. Jour. Geol. Soc., vol. 16.

SOLARIIDÆ.

Straparollus Montfort, 1810, Conch. Syst., vol. 2.
planorbis.
subrugosus Meek and Worthen, 1873, Geol. Surv., vol. 5.
umbilicatus Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.

NATICIDÆ.

Trachydomia Meek and Worthen, 1866, Geol. Surv. Ill., vol. 2.
nodosum Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.

TROCHIDÆ.

Turritella (accilisina Zittel) Lamarck, 1801, Syst. An. sans Vert.
stevensana Meek and Worthen, 1866, Geol. Surv. Ill., vol. 2.

HYALIDÆ.

Conularia (a Pteropod) Miller, 1818, in Sowerby's Min. Conch., vol. 3.
crustula or *cristula.*

CLASS CEPHALOPODA.

CYRTOCERATIDÆ.

Cyrtoceras Goldfuss, 1832, in De la Beche's Handbuch der Geognoise bearbeitet von v Deschen.
——— sp.

GONIATITIDÆ.

Goniatites De Hann, 1825, Monogr. Ammonites et Goniatites.
lyoni Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
planorbiformis Shumard, 1855, Geol. Surv. Mo.

NAUTILIDÆ.

Nautilus Breynius, 1732, Dissert. Polyth.
eccentricus Meek and Hayden, 1858, Trans. Alb. Inst., vol. 4.
ferratus Cox, 1857, Geol. Surv. Ky., vol. 3.
globosus (*globatus*) Sowerby, 1825, Min. Conch.
lasellensis Meek and Worthen, 1866, Proc. Acad. Nat. Sci. Phil.
missouriensis Swallow, 1858, Trans. St. Louis Acad. Sci.
occidentalis Swallow, 1858, Trans. St. Louis Acad. Sci.
planovolvis Shumard, 1858, Trans. St. Louis Acad. Sci.

Nautilus Breynius, 1732, Dissert. Polyth.
ponderosus White, 1872, Pal. of E. Neb.
sangamonensis Meek and Worthen, 1860, Proc. Acad. Nat. Sci. Phil.
todanus ———
——— sp.

ORTHOCERATIDÆ.

Orthoceras Breynius, 1732, Dissert. Polyth.
cribrosum Geinitz, 1866, Carb. und Dyas in Neb.
munstrianum ———
rushense McChesney, 1860, New. Pal. Foss.

Branch VI.—ARTHROPODA.

Class CRUSTACEA.

Four genera and six species.

PENÆIDÆ.

Anthraccopalæmon or **Anthropalæmon** Salter, 1861, Quar. Jour. Geol. Soc. Lond., vol. 17.
——— sp.

PHYLLOCARDÆ.

Dithyrocaris Scouler, 1855, Brit. Pol. Rocks.
carbonaria Meek and Worthen, 1869, Proc. Acad. Nat. Sci. Phil.

AMPHIPODA.

Palæocaris Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.
typus Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.

PRŒTIDÆ.

Phillipsia Portlock, 1843, Rep. Geol. Londonderry.
cliftonensis Shumard, 1858, Trans. St. Louis Acad. Sci.
major Shumard, 1858, Trans. St. Louis. Acad. Sci., vol. 1.
scitula Meek and Worthen, 1865, Proc. Acad. Nat. Sci. Phil.

Branch VII.—VERTEBRATA.

The teeth, dermal plates and scales of fish, and occasionally a fin bone, have been gathered. Those known to us are of the following genera and species:

Peripristes Newberry and Worthen, 1866, Geol. Surv. Ill., vol. 2.
semicircularis Newberry and Worthen, 1868, Geol. Surv. Ill., vol. 2.
clenoptychus.
Petalodus Owen, 1840, Odontography.
alleghaniensis Leidy, 1856, Jour. Acad. Nat. Sci. Phil., 2d series, vol. 3.
destructor Newberry and Worthen, 1866, Geol. Surv. Ill., vol. 2.
Petrodus McCoy, 1848, Ann. and Mag. Nat. Hist., 2d series, vol. 2.
occidentalis Newberry and Worthen, 1866, Geol. Surv. Ill., vol. 2.

ARRANGEMENT BY COUNTIES.

The following is a tabulated list, by counties, of the invertebrate fauna of the Carboniferous of Kansas. The more exact geographic position is often given by adding the name of the town at or near which the specimen was found. Many of the specimens in the University museum are labeled with reference to geographic position only, so that no information can be gained regarding the geologic position from which they came. Where it is known from what particular horizon a specimen came the position is indicated by a system of figures which are added to the name. Thus:

1 — Cherokee shales.
2 — Black shales just below the Oswego limestone.
3 — Lower Oswego limestone.
4 — Black shale between the two Oswego limestones.
5 — Upper Oswego limestone.
6 — Pawnee limestone.
7 — Eight-foot limestone within the Pleasanton shales.
8 — Lower Erie limestone.
9 — Middle Erie limestone.
10 — Upper Erie limestone.
11 — Iola limestone and shales abovo.
12 — Carlyle limestone.
13 — Lower Garnett limestone.
14 — Upper Garnett limestone.
15 — Lawrence shales, with included limestone.
16 — Lower Oread limestone.
17 — Upper Oread limestone.
18 — Lecompton limestones.
19 — "Dry-bone" limestone of Swallow, lying about 30 feet below the Cottonwood Falls limestone.
20 — Cottonwood Falls limestone.
21 — Cottonwood shales.
22 — Oolite limestone at Kansas City.

ALLEN COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Iola, 12.

CŒLENTERATA.

Cyathaxonia *distorta*, Iola, 12.
Lophophyllum *proliferum*, Iola, 12.

ECHINODERMATA.

Archæocidaris ———, Iola, 12.
Erisocrinus *typus*, Iola, 12.
Scaphiocrinus *hemisphericus*, Iola, 12.

Zeacrinus *acanthophorus*, Iola, 11, 12.
mucrospinus, Iola, 11, 12.

MOLLUSCA.

BRYOZOA.

Fenestella ——, Iola, 12.
Synocladia *biserialis*, Iola, 12.

BRACHIOPODA.

Athyris *subtilita*, Bronson and Iola, 10, 11, 12.
Chonetes *verneuiliana*, Bronson and Iola, 10, 11, 12.

Orthis *carbonaria*, Iola, 12.
Productus *longispinus*, Iola, 11, 12.
nebrascensis, Bronson and Iola, 10, 12.
pertenuis, Bronson and Iola, 10, 11, 12.
punctatus, Bronson and Iola, 10, 11, 12.
semireticulatus, Iola, 12.
symmetricus, Iola, 12.
Retzia *mormoni*, Iola, 11, 12.
Rhynchonella *uta*, Iola, 12.
Spirifera *camerata*, Bronson and Iola, 10, 11, 12.
lineata, Iola, 11, 12.
plano-convexa, Iola, 12.
Spiriferina *kentuckiensis*, Iola, 12.
Streptorhynchus *crassus*, Iola, 12, Syn. for Derbya.
Terebratula *bovidens*, Bronson and Iola, 10, 11, 12.

LAMELLIBRANCHIATA.

Allorisma *granosa*, Iola, 12.
Aviculopecten *carboniferous*, Iola, 12.
interlineatus, Iola, 12.
Edmondia *aspinwallensis*, Bronson, 10.

GASTEROPODA.

Platyceras *nebrascensis*, Iola, 12.
Pleurotomaria ——, Iola, 11.

CEPHALOPODA.

Nautilus *ferratus*, Bronson and Iola, 10, 11.
missouriensis, Humboldt, 11.
occidentalis, Bronson, 10.
—— sp., Iola, 12.
Orthoceras —— sp., Bronson, 10.

ARTHROPODA.

Phillipsia *major*, Iola, 12.

VERTEBRATA.

A fish tooth, Iola, 12.

REMARKS.—The top rock of the Triple system is very fossiliferous wherever found, from its equivalent — the black cherty limestone of Kansas City — to the southern line of the state, beyond Cherryvale. Under it the list of fossils might be much increased. What was gathered from it was from a well on Mr. McLaughlin's farm, southeast of Moran, a station on the Missouri Pacific railway, and along the Marmaton river, near the same farm.

ANDERSON COUNTY.

CŒLENTERATA.

Axophyllum *rudis*, Garnett.
Campophyllum *torquium*, Garnett.
Lophophyllum *proliferum*, Garnett.
Syringopora *multattenuata*, Garnett.

ECHINODERMATA.

Columns of *Crinoidea*, Garnett.

MOLLUSCA.

BRYOZOA.

Polypora *stragula*, Garnett.
submarginata, Garnett.
Synocladia *biserialis*, Garnett.

BRACHIOPODA.

Athyris *subtilita*, Garnett.
Chonetes *verneuiliana*, Garnett.
Derbya ——— sp., Garnett.
Hemipronites *crassus*, Garnett.
Meekella *striato-costata*, Garnett.
Orbiculoida ? ——— sp., Garnett.
Productus *nebrascensis*, Garnett.
punctatus, Garnett.
semireticulatus, Garnett.
Terebratula *bovidens*, Garnett.

LAMELLIBRANCHIATA.

Allorisma *granosa*, Garnett.
subcuniata, Mt. Ida.
Aviculopecten *carbonaria*, Garnett.
occidentalis, Garnett.
Macrodon ——— sp., Garnett.
Myalina *kansasensis*, Garnett.
subquadrata, Garnett.
Pleurophorus *oblongus*, Mt. Ida.
Pinna *subspatulata* ? Garnett.
peracuta, Garnett.
Schizodus *wheeleri* ? Garnett.

GASTEROPODA.

Bellerophon *crassus*, Garnett.
Euomphalus *rugosus*, Mt. Ida.
subrugosus, Garnett.
Loxonema *rugosa*, Garnett.
——— sp., Garnett.
Naticopsis *altonensis*, Garnett.
——— sp., Garnett.
Pleurotomaria *tabulata*, Garnett and Mt. Ida.
turbiniformis, Garnett.
——— sp., Garnett.

CEPHALOPODA

Nautilus *ferratus*, Garnett.
occidentalis, Garnett.
ponderosus, Garnett and Lane.

REMARKS.—It would be safe to say that all the fossils of the Garnett limestone (see chapter VI) and the first limestone above it are to be found in this county, as at Eudora in Douglas county, Linwood in Leavenworth county, and Olathe in Johnson county.

ATCHISON COUNTY.

PROTOZOA.

Fusulina *cylindrica.*

CŒLENTERATA.

Axophyllum *rudis.*
Lophophyllum *proliferum.*
Syringopora *multattenuata.*

ECHINODERMATA.

Archæocidaris ———sp.
Zeacrinus *acanthophorus.*
mucrospinus.

MOLLUSCA.

BRYOZOA.

Chætetes ———sp.
Fenestella ———sp.
Fistulipora *nodulifera.*
Rhombopora *lepidodendroides.*

BRACHIOPODA.

Athyris *subtilita.*
Chonetes *granulifera.*
verneuiliana.
Orthis (*carbonaria*) *pecosi.*
Productus *longispinus.*
nebrascensis.
pertenuis.
prattenianus.
punctatus.
Retzia *mormoni.*
Spirifera *camerata.*
lineata.
Spiriferina *kentuckiensis.*
Terebratula *bovidens.*

LAMELLIBRANCHIATA.

Allorisma *subcuneata.*
Aviculopecten *occidentalis.*
Edmondia *subtruncata.*

Myalina *subquadrata.*
Nucula *ventricosa.*
Nuculana *bellistriata.*
Pinna *peracuta.*
Solenopsis *solenoides.*

GASTEROPODA.

Bellerophon *crassus.*
montfortanus.
Euomphalus *rugosus.*
Macrocheilus ——— sp.
Pleurotomaria *tabulata.*

CEPHALOPODA.

Nautilus *occidentalis.*

ARTHROPODA.

Phillipsia *major.*

REMARKS.—All the above-named fossils are from the city of Atchison, gathered mainly by myself years ago, and duplicated by more recent collections. For the individual fossils found in any particular limestone or shale, see chapter on the Missouri river section.

BOURBON COUNTY.

PROTOZOA.

Fusulina *cylindrica.*
ventricosa ? 3.

CŒLENTERATA.

Axophyllum *rudis*, 3, 5, 6.
Campophyllum *torquium*, 3, 6.
Cyathaxonia *distorta*, 3, 6, 7.
Lophophyllum *proliferum*, 3, 5, 6, 7.
Syringopora *multattenuata*, 3.
Zaphrentis *gibsoni* ? 5.

ECHINODERMATA.

Archæocidaris ——— sp., 3.
(Large) columns of *Crinoidea*, 3, 5, 6, 7, 8, 9, 10.
Zeacrinus *mucrospinus*, 3, 6.
——— sp., 3.

MOLLUSCA.

BRYOZOA.

Chætetes *carbonarius* ? 3, 8.
milleporaceus, 3, 5, 6.
Fenestella ———, 3, 5, 6.
Fistulipora *nodulifera*, 3, 5, 6, 8.
Ptilodictya ? *triangulata*, 3.
Rhombopora *lepidodendroides*, 3.

BRACHIOPODA.

Athyris *lamellosa*, 3, 6.
subtilita, 3, 5, 6, 7, 8, 9, 10.
trinuclia, 7.
Chonetes *granulifera*, 8.
verneuiliana, 8.
mesoloba, 3, 4, 5, 6, 7.
Last seen in the 8-foot limestone system.
——— sp., 3, 6, 8.
Discina *nitida*, 3, 5, 6, 7, 8.
Meekella *striato-costata*, 3.
Orthis (*carbonaria*) *pecosi*, 3.
robusta, 8.
Productus *americana*, 3, 8, 9, 10.
costatus, 3, 8, 10.
longispinus, 3, 5, 6, 7, 8, 9, 10.
nebrascensis, 3, 8.
pertenuis, 3.
punctatus, 3.
symmetricus, 8.
Retzia *mormoni*, 3, 5, 6, 7, 8, 9, 10.
Rhynchonella *uta*, 3, 7.
Spirifera *camerata*, 3, 7, 8, 9, 10.
lineata, 4, 5, 6, 7.
plano-convexus, 3, 4, 5, 6, 7.
Spiriferina *kentuckiensis*, 3, 6, 8.
Streptorhynchus *crassus*, 3, 5.
Terebratula *bovidens*, 8.

LAMELLIBRANCHIATA.

Allorisma *subcuneata*, 8, 10, Porterville.
——— sp., 3.
Aviculopecten ——— sp., 5.
Edmondia *aspinwallensis*, 10.
nebrascensis, 3.
Nucula *ventricosa*, 3, 5.

Nuculana *bellistriata*, 3, 5.
Pinna *peracuta*, Porterville, 10.
Schizodus *wheeleri*, 3.
Sp. (very large), 3.
——— sp., 5.

GASTEROPODA.

Bellerophon *carbonaria*, 5.
marcouanus, 5.
montfortanus, 3.
percarinatus, 3, 4, 5.
——— sp., 3, 5, 6.
Euomphalus *rugosus*, 5.
Macrocheilus *primigenius*, 3.
Loxonema *rugosa* ? 3, 5.
intercalaris, 3, 5.
Naticopsis *altonensis*, 3, 5.
ventricosa, 3, 6.
Pleurotomaria *broadheadi*, 3, 4.
speciosa, 3.
sphærulata, 3, 4, 6.
turbiniformis, 3.
——— sp., 3, 5.
Polyphemopsis Accilisina ——— sp., 3.
Conularia (a Pteropod) *crustula*, 3.

CEPHALOPODA.

Goniatites ——— sp., 3, 4, 5.
Nautilus *ferratus*, Porterville, 10.
occidentalis, 3.
——— sp., 3, 6.
Orthoceras *rushense*, 3, 5.
——— sp., 3.
——— sp., Porterville, 3.

ARTHROPODA.

Dithyrocaris ——— sp., 3.
Phillipsia *major*, 3, 10.

VERTEBRATA.

Petrodus *occidentalis*, 3, 4, 7.
Scales and dermal plates of fish, 3, 4, 5.
Spines of fish, 3, 4, 5.

PLANTÆ.

Calemites, 3.
Filices or ferns, 3.
Lepidodendroids, 3.
Sigillarioids, 3.

REMARKS.—The families named here are found in all the lower shales at least, but none have been identified as to species.

BROWN COUNTY.

CŒLENTERATA.

Lophophyllum *proliferum*.

ECHMODERMATA.

Zeacrinus *acanthophorus*.
——— sp.
Crinoid columns.

MOLLUSCA.

BRYOZOA.

Fenestella ———
Rhombopora *lepidodendroides*.

BRACHIOPODA.

Athyris *subtilita*.
Chonetes *glabra ?*
granulifera.
Hemipronites *crassus*.
Productus *nebrascensis*.
costatus ?
Spirifera *plano-convexus*.

LAMELLIBRANCHIATA.

Astartella *concentrica*.
Aviculopecten *occidentalis*.
maccoyi ?
Edmondia *nebrascensis*.
Myalina *recurvirostris*.
subquadrata.
Macrodon ———.
Nucula *ventricosa*.

GASTEROPODA.

Bellerophon ———

CEPHALOPODA.

Orthoceras *munstrianum ?*
rushense.

REMARKS.—The above fossils were gathered by me several years ago near the village of Hamlin on the St. Joseph & Grand Island railroad. What the corresponding rock south of the Kansas river is, we are not prepared to say, our work not having extended that far north.

BUTLER COUNTY.

PROTOZOA.

Fusulina *robusta*, Beaumont.

MOLLUSCA.

BRACHIOPODA.

Meekella *striato-costata.*
Retzia *mormoni*, Beaumont.
Rhynchonella *uta*, Beaumont.

LAMELLIBRANCHIATA.

Allorisma *subcuniata.*
Aviculopecten *occidentalis.*
Edmondia *aspinwallensis*, Beaumont.
Myalina *kansasensis*, Beaumont.

GASTEROPODA.

Dentalium ———, Beaumont.

REMARKS.—For the above list we had to depend on the specimens found in the University museum. Unquestionably many of the fossils of the higher strata could be found in the county.

CHASE COUNTY.

PROTOZOA.

Fusulina *cylindrica*, 20.

MOLLUSCA.

BRACHIOPODA.

Chonetes *granulifera*, 20.
Meekella *striato-costata*, 20.
Productus *semireticulatus*, 19.
Streptorhynchus (*Hemipronites*) *crassus*, 20.

CHAUTAUQUA COUNTY.

But a single fossil has been reported from this county, *Bellerophon textilliformis*, yet we have the strongest reason for saying that all the fossils of the counties northeast of it might reasonably be looked for in it. All the limestone systems trending across the counties northeast of it, in a southwesterly direction, are to be found in this county, from which they leave the state at the Indian Territory line.

CHEROKEE COUNTY.

CŒLENTERATA.

Cyathophyllum ——— sp., Galena.
Zaphrentis ——— sp., Galena.

ECHINODERMATA.

Platocrinus ——— sp., Galena.
Pentremites *godoni* ? Galena.
Strotocrinus ——— sp., Galena.
Columns of *crinoidea*, Galena.

MOLLUSCA.

BRYOZOA.

Archimedes ——— sp., Galena.
Fenestella ——— sp., Galena.
Ptilodictya ? ——— sp., Galena.

BRACHIOPODA.

Chonetes ——— sp., Galena.
Orbiculoida ? ——— sp., Galena.
Orthis *keokuk* ? Galena.
——— sp., Galena.
Productus *americanus*, 3 or 5.
costatus, 3 or 5.
magnus, Galena and Boston Mills.
punctatus ? Galena.
punctatus, 3 or 5.
semireticulatus, 3 or 5.
symmetricus, Galena.
tenuicostatus, Galena.
Spirifera *fastigatus*, Galena.
keokuk, Galena and Boston Mills.
lineata, 3 or 5.
rostellatus, Galena.
suborbicularis, Galena.
Streptorhynchus (*Hemipronites*), ———, Galena.

LAMELLIBRANCHIATA.

Allorisma *antiqua* ? Galena.
Aviculopecten *coxanus* ? Galena.
———, sp., Galena.
———, sp., Galena.

GASTEROPODA.

Dentalium ——— sp., Galena.
Murchisonia ——— sp., Galena.
Platyceras *equilatera* ? Galena.

CEPHALOPODA.

Orthoceras ——— sp., Galena.
Nautilus *planovolvis*, ? 1.
——— sp., 1.

ARTHROPODA.

Phillipsia ———, Galena.
major, 3 or 5.

VERTEBRATA.

Fish spines and teeth, Galena.

The two Nautilidæ here given are specimens in Professor Haworth's collection, and were found in concretionary limestone just above the Weir City-Pittsburg coal.

REMARKS.—We may reasonably look for all the fossils of the Oswego limestone systems — the equivalents of the Fort Scott cement and coral limestones and their associated black shales — which pass across the northwestern corner of this county, such, for instance, as the *Chætetes milliporaceus*, *Discina nitida*, *Chonetes mesoloba*, etc.

It will also be seen that we have gone below the Coal Measure formations in our list of fossils, part of the above species being found in the Mississippian rocks of Galena and the neighborhood. In all other places in this chapter they are not separated from the fossils actually found in the Coal Measures.

COFFEY COUNTY.

MOLLUSCA.

BRYOZOA.

Rhombopora *lepidodendroides*, Burlington.

BRACHIOPODA.

Meekella *striato-costata*, Burlington.
Productus *punctatus*, Burlington.
semireticulatus, Burlington.
Streptorhynchus (Hemipronites) *crassus*, Burlington.

LAMELLIBRANCHIATA.

Myalina *recurvirostris*, Burlington.
subquadrata, Burlington.

GASTEROPODA.

Loxonema ——— sp., Hartford.

REMARKS.—This list undoubtedly could be very much lengthened by closer observation and search; for the Oread limestone systems are known to be very highly fossiliferous (see Douglas county), and they cross Coffey county in their croppings and trend toward the southwest.

COWLEY COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Grand Summit.

CŒLENTERATA.

Axophyllum *rudis*, Grand Summit and Cambridge.

Lophophyllum *proliferum*, Grand Summit.

ECHINODERMATA.

Archæocidaris *mucronatus*.

Scaphiocrinus *hemisphericus*, Grand Summit.

MOLLUSCA.

BRYOZOA.

Fistulipora *nodulifera*, Grand Summit.

Rhombopora *lepidodendroides*, Grand Summit.

BRACHIOPODA.

Athyris *subtilita*, Grand Summit.

Chonetes *granulifera*, Grand Summit.

Derbya ——— sp.

Meekella *striato-costata*, Grand Summit.

Productus *nebrascensis*, Grand Summit.

pertenuis, Grand Summit.

semireticulatus, Grand Summit.

symmetricus, Grand Summit. Several *crania* were attached to this specimen in the University museum.

Retzia *mormoni*, Grand Summit.

Rhynchonella *uta*, Grand Summit.

Spirifera *camerata*, Grand Summit.

lineata, Grand Summit.

Syntrialasma *hemiplicata*, Grand Summit.

Terebratula *bovidens*, Grand Summit.

LAMELLIBRANCHIATA.

Allorisma *granosa*, Grand Summit.

marionensis, Grand Summit.

(sanguinolites) *obliqua*, Grand Summit.

reflexa, GrandSummit.

Astarte ——— sp., Grand Summit.

Aviculopecten *maccoyi*, Grand Summit.

occidentalis, Grand Summit.

——— sp., Grand Summit.

Lima *retifera*, Grand Summit.

Myalina *kansasensis*, Grand Summit.

subquadrata, Grand Summit.

swallovi, Grand Summit.

Nucula *parva*, Grand Summit.

ventricosa, Grand Summit.

Nuculana ——— sp., Grand Summit.

Prothyris *elegans*, Grand Summit.

Pseudomonotis *hawni*, Grand Summit.

Pleurophorus ——— sp., Grand Summit.

Schizodus *wheeleri*.

Yoldia *subscitula*, Grand Summit.

GASTEROPODA.

Bellerophon ——— sp. (*flaring lip*), Grand Summit.

marcouanus, Grand Summit.

Dawsonella *meeki*, Grand Summit.

Naticopsis ——— sp., Grand Summit.

Macrocheilus *angulifera*, Grand Summit.

primevus, Grand Summit.

Pleurotomaria *marcouana*, Grand Summit.

Straparollus *rugosus*, Grand Summit.

——— sp., Grand Summit.

CEPHALOPODA.

Goneatites *planorbiformis*, Grand Summit.

Orthoceras *rushense*, Grand Summit.

ARTHROPODA.

Phillipsia *scitula*.

REMARKS.—We are indebted to Mr. Adams for so full a list from this county, which is undoubtedly rich in faunal exuviæ, as many fine specimens in the University and Mr. Adams's private collection will show.

CRAWFORD COUNTY.

CŒLENTERATA.

Axophyllum *rudis*, Englevale, 5.

Lophophyllum *proliferum*, Englevale and Girard.

ECHINODERMATA.

Pentremites *conoidens*, 1.

This fossil came from the neighborhood of Pittsburg, probably from a shaft that reached down toward the Mississipian rocks.

Columns of *crinoidea*, Englevale and Girard, 3, 5.

MOLLUSCA.

BRYOZOA.

Chætetes *milleporaceus*, Englevale and Girard, 3, 5.

BRACHIOPODA.

Athyris *subtilita*, Englevale and Girard, 3, 5.

Discina *nitida*, 3, 5.

Productus *cora*, Girard, 5.

Spirifera *plano-convexus*, 3, 5.

lineata, 3, 5.

LAMELLIBRANCHIATA.

Allorisma *reflexa*, Girard, 5.

REMARKS.—All the fossils of the Cement, Coral and Pawnee limestones of Bourbon county may reasonably be looked for in this county, although these limestone systems are very much more concealed in it than in Bourbon county. The Erie system also has a small area in the northwestern part of the county. The coal plants are also found in the shales, and fine samples of silicified stumps are found especially in the northeastern part of the county.

DOUGLAS COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Lawrence, 16, 17.

CŒLENTERATA.

Campophyllum *torquium*, Lecompton, 17.

Cyathaxonia *distorta*, Lecompton, 17.

Lophophyllum *proliferum*, Lawrence and Lecompton, 17.

Syringopora *multattenuata*, Lecompton, 17.

ECHINODERMATA.

Archæocidaris —— sp., Lecompton, 17.

Eupachycrinus —— sp., Lecompton, 17.

Scaphiocrinus *hemisphericus*, Lecompton, 17.

Zearcrinus *discus*.

MOLLUSCA.

BRYOZOA.

Chætetes —— sp., Lawrence and Lecompton, 17.

Fenestella —— sp., Eudora, 13.

Fistulipora *nodulifera*, Lecompton, 17.

Synocladia *biserialis*, Lecompton, 17.

BRACHIOPODA.

Athyris *subtilita*, Eudora, Lawrence, and Lecompton, 13, 14, 16, 17.

Chonetes *granulifera*, Lecompton, 17.
verneuiliana, Lecompton, 17.
Derbya *bennetti*, Lecompton, 17.
broadheadi, Lecompton, 17.
Discina *nitida*, 15.
Meekella *striato-costata*, Lecompton, 17.
Orthis (*carbonaria*) *pecosi*, Lawrence and Lecompton, 16, 17.
robusta, Lecompton, 17.
Productus *altonensis*, Lecompton, 17.
americanus, Eudora and Lecompton, 13, 17.
costatus, Lecompton, 17.
longispinus, Eudora and Lecompton, 13, 17.
nebrascensis, Eudora and Lecompton, 13, 17.
pertenuis, Eudora, 13.
punctatus, Lecompton, 17.
semireticulatus, Lecompton, 17.
symmetricus, Lecompton, 17.
Retzia *mormoni*, Lecompton, 17.
Rhynchonella *uta*, Lecompton, 17.
Spirifera *camerata*, Lecompton, 17.
lineata, Lecompton, 17.
plano-convexus, Lecompton, 17.
Spiriferina *kentuckiensis*, Lawrence and Lecompton, 17.
Streptorhynchus *crassus*, Lecompton, 17.
Syntrialasma *hemiplicata*, Eudora and Lecompton, 13, 17.
Terebratula *bovidens*, Eudora and Lecompton, 13, 17.

LAMELLIBRANCHIATA.

Allorisma *costata*, Lawrence, 16.
granosa, Lawrence, 16.
regularis, Lawrence, 16.
Astarte ——— sp.
Avicula *longa*, Lecompton, 17.
Aviculopecten *carboniferus*.
Chænocardia *ovata*, Lecompton, 17.
Chænomya *leavenworthensis*, Lecompton, 17.
Edmondia *nebrascensis*, Lecompton, 17.
Entolium *avicula*.
Macrodon ——— sp., Lecompton, 17.
Monoptera *marian*, Lecompton, 17.
Myalina *recurvirostris*, Eudora and Lecompton, 13, 17.
swallovi, Eudora, 13.
Nucula ——— sp., Lecompton, 17.
Pinna *peracuta*, Lecompton, 17.
Schizodus *wheeleri*, Eudora, 13.
——— sp., Lecompton, 17.
——— sp., Lecompton, 17.

GASTEROPODA.

Bellerophon *carbonarius*, Lecomton, 17.
crassus, Lecompton, 17.
Euomphalus *subrugosus*, Lecompton, 17.
Macrocheilus *altonensis* ? Lecompton, 17.
Pleurotomaria *bonharborensis*, Lecompton, 17.
carbonaria, Lecompton, 17.
turbiniformis, Eudora and Lecompton, 13, 17.

CEPHALOPODA.

Nautilus *occidentalis*, Lecompton, 17.
sangamonensis, Lecompton, 17.
Orthoceras *munstrianum*, Lawrence and Lecompton, 16, 17.

ARTHROPODA.

Palæocaris *typus*.
Phillipsia *major*, Lecompton, 17.

REMARKS.—The Lawrence shales in the neighborhood of Blue Mound yield some fine specimens of the fern family and other Coal Measure plants. Nowhere outside of the lower Garnett limestone at Eudora have we found *syntrialasma* in such abundance and so well preserved as here, except just across the Kansas river west of Linwood three miles, in Leavenworth county. They are quite plentiful, however, in this rock north of Olathe, in Johnson county, and in the bed of the Osage river at Ottawa, in Franklin county.

ELK COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Elk Falls.

CŒLENTERATA.

Axophyllum *rudis*, Moline.
Syringopora *multattenuata*, Elk Falls.

ECHINODERMATA.

Scaphiocrinus *hemisphericus*, Moline.

MOLLUSCA.

BRACHIOPODA.

Chonetes *granulifera*.
verneuiliana, Moline.
Derbya ——— sp., near Grenola.
Productus *americanus*, Moline.
punctatus, Moline.
nebrascensis.
Spirifera *camerata*, Moline.
lineata, Elk Falls.
Streptorhynchus (*Hem.*) *crassus*.

LAMELLIBRANCHIATA.

Allorisma *subcuniata*.
Aviculopecten *coxanus*, Grenola.
Pseudomonotis *hawni*.

CEPHALOPODA.

Nautilus *ferratus*.
——— sp., Moline.

FRANKLIN COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Williamsburg.

CŒLENTERATA.

Campophyllum *torquium*, Williamsburg.
Lophophyllum *proliferum*, 14.

ECHINODERMATA.

Crinoidea, Williamsburg, 13, 14.

MOLLUSCA.

BRYOZOA.

Fenestella ——— sp., 13, 14.
Fistulipora *nodulifera*, 13, 14,

BRACHIOPODA.

Athyris *subtilita*, Williamsburg, 13, 14.
Chonetes *verneuiliana*, Williamsburg.
Derbya ——— sp., Williamsburg.
Productus *costatus*, 14.
longispinus, 13, 14, Williamsburg.
nebrascensis, 14.
punctatus, 13, 14.
Spirifera *camerata*, 14.
Syntrialasma *hemiplicata*, 13.

LAMELLIBRANCHIATA.

Aviculopecten *carboniferus*, 13.
Pinna *peracuta*, 14.
Posidonomya *fracta*, Williamsburg.

GASTEROPODA.

Bellerophon *marcouanus*, Williamsburg.
Loxonema ——— sp., Williamsburg.
Straparollus ——— sp., 14.

CEPHALOPODA.

Nautilus *ponderosus*, 14.
sangamonensis.

REMARKS.—The Syntrialasma and upper Eudora and Oread limestones traverse this county, in their croppings, so that all the fossils of those systems might reasonably be looked for.

GREENWOOD COUNTY.

CŒLENTERATA.

Lophophyllum *proliferum*, Eureka.

ECHINODERMATA.

Columns of *crinoidea*, Eureka.

MOLLUSCA.

BRACHIOPODA.

Athyris *subtilita*, Eureka.
Retzia *mormoni*, Eureka.
Spirifera *plano-convexus*.

LAMELLIBRANCHIATA.

Allorisma *granosa*.
Myalina *kansasensis*.

CEPHALOPODA.

Nautilus *planovolvis*.

REMARKS.—All the fossils of the higher strata may reasonably be looked for here.

JEFFERSON COUNTY.

ECHINODERMATA.

Archæocidaris *edgarensis*.
Catillocrinus *wachsmuthi*.
Cyathocrinus *sangamonensis*.
Eupachyocrinus —— sp.
Pholidocrinus ? *irregularis*.

MOLLUSCA.

BRACHIOPODA.

Chonetes *verneuiliana*.
Productus *nebrascensis*.

LAMELLIBRANCHIATA.

Yoldia *subscitula*.

GASTEROPODA.

Bellerophon *marcouanus*.
Macrocheilus *newberryi*.

VERTEBRATA.

Fish teeth.

REMARKS.—Our observations did not extend to this county, but in the University museum the above fossils were found reported from this county, no locality being given. Undoubtedly many of the fossils of the Oread limestones may be had, as all the Douglas county systems of limestones are present.

JOHNSON COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Olathe, 14.

CŒLENTERATA.

Campophyllum *torquium*, Cedar Junction.
Lophophyllum *proliferum*, Olathe, 14.

ECHINODERMATA.

Eupachycrinus —— sp., Cedar Junction.
Zeacrinus *acanthophorus*, Cedar Junction.
mucrospinus, Cedar Junction.
Columns of *crinoidea*, Olathe, Holliday, Cedar Junction, De Soto, and Weaver, 11, 13, 14, 22.

MOLLUSCA.

BRYOZOA.

Fenestella —— Holliday, 22.
Fistulipora *nodulifera*, Olathe, 14.

Synocladia *biserialis*, Olathe, Holliday, 13, 22, 11.

BRACHIOPODA.

Athyris *subtilita*, Olathe, Holliday, Cedar Junction, De Soto, and Weaver, 11, 13, 14, 22.
Chonetes *verneuiliana*, Cedar Junction, Olathe, 13.
Meekella *striato-costata*, Olathe, 14.
Orbiculoida ? —— sp., Holliday, 22.
Orthis (*carbonaria*) *pecosi*, Olathe, 14.
robusta, Holliday, 22.
Productus *americanus*, Olathe, 13.
costatus, Olathe, Holliday, Cedar Junction, 13, 22.
longispinus, Olathe, 13, 14.
nebrascensis, Olathe, Cedar Junction, Holliday, 13, 14, 22.
prattenianus, Holliday, 22.
punctatus, Cedar Junction, Olathe, 14.
symmetricus, Holliday, 22.
Retzia *mormoni*, Olathe, Holliday, 13, 14, 22.
Rhynchonella *uta*, Olathe, 14.
Spirifera *camerata*, Olathe and Holliday, 13, 14, 22.
lineata, Olathe and Holliday, 14, 22.
Spiriferina *kansasensis*, Olathe and Holliday, 14, 22.
Syntrialasma *hemiplicata*, Olathe, 13.
Terebratula *bovidens*, Olathe and Holliday, 13, 22.

LAMELLIBRANCHIATA.

Allorisma *costata*, Holliday, 22.
reflexa, Olathe, 13.
subcuneata, Weaver and Holliday, 13, 22.
striata.
Aviculopecten *carboniferus*, Holliday and De Soto, 11, 22.
occidentalis, De Soto and Weaver, 13, 22.
Cypricardina ? *carbonaria*, Holliday, 22.
Edmondia *nebrascensis*, Holliday, 22.
Macrodon *carbonarius*, Holliday, 22.
Myalina *subquadrata*, Holliday, 22.
swallovi, Holliday, 22.
Pseudomonotis *hawni*, Holliday, 22.
—— sp., Holliday, 22.

GASTEROPODA.

Bellerophon *crassus* ? Holliday, 22.
textilliformis, Holliday, 22.
sp. (*flaring mouth*) Holliday, 22.
Conularia *crustula*, Holliday, 22.

CEPHALOPODA.

Nautilus *todanus*, Holliday, 22.
—— sp., Holliday, 22.

ARTHROPODA.

Phillipsia *major*, Olathe and Holliday, 13, 22.

LABETTE COUNTY.

PROTOZOA.

Fusulina *cylindrica*.

CŒLENTERATA.

Campophyllum *torquium*, O.
Lithostrotion *canadense*, Cast.
Lophophyllum *proliferum*, McCh.

ECHINODERMATA.

Archæocidaris *nov.* ?
Archocidaris *ag.* ?

MOLLUSCA.

BRYOZOA.

Chætetes *milleporaceus*.
? —— sp.

BRACHIOPODA.

Athyris *subtilita*, Hall.
Chonetes *mesoloba.*
Hemipronites *crassus*, M. and H.
Productus *americanus*, Mound Valley.
costatus.
longispinus ?
nebrascensis, O.
punctatus, M. and H.
semireticulatus, M.
symmetricus, McCh.
Spirifera *camerata*, Norton.
plano-convexus, Shumard.
Spiriferina *kentuckiensis*, Shumard.

LAMELLIBRANCHIATA.

Allorisma *subcuneata.*
——— sp.
Aviculopinna *americana.*
Edmondia ?
Pinna *peracuta*, Shumard.

GASTEROPODA.

Bellerophon *carbonarius*, Cox.
——— sp.
Euomphalus *rugosus.*
Macrocheilus ? ——— sp.
Platyceras *nebrascensis*, Meek.
Pleurotomaria ?
——— sp., Mound Valley.

CEPHALOPODA.

Asymtoceras *newloni*, Hyatt.
Domatoceras *umbilicatus*, Hyatt.
Ephoppioceras *divisum*, Hyatt.
Metacoceras *walcotti*, Hyatt.
Temnocheilus *crassus*, McCoy.
latus, M. and W.

REMARKS.—Except for the two fossils credited to Mound Valley, we are due to Dr. W. S. Newlon, of Oswego, for the foregoing list. All the fossils of the Oswego limestones as given elsewhere may reasonably be looked for in the county. Doctor Newlon gave his list largely from memory, and said that it could be greatly increased.

LEAVENWORTH COUNTY.

PROTOZOA.

Fusulina *cylindrica.*

CŒLENTERATA.

Lophophyllum *proliferum*, Linwood and Leavenworth.

ECHINODERMATA.

Archæocidaris ——— sp., Linwood.
Zeacrinus *mucrospinus*, Linwood.

MOLLUSCA.

BRYOZOA.

Fenestella ——— sp., Lenape and Linwood.
Fistulipora *nodulifera*, Linwood and Leavenworth.

BRACHIOPODA.

Athyris *subtilita*, Lenape, Linwood, Leavenworth, and Lansing.
Productus *americanus*, Linwood.
longispinus, Lenape and Linwood.
nebrascensis, Lenape and Linwood.
punctatus, Lansing.
Spirifera *camerata*, Linwood and Lansing.
Streptorhynchus *imbraculum*, Lansing.
Syntrialasma *hemiplicata*, Linwood.
Terebratula *bovidens*, Linwood.

LAMELLIBRANCHIATA.

Aviculopecten *americana*, Lansing.
occidentalis, Lansing.
rectilaterarius, Lansing.
Aviculopinna *americana*, Lansing.
Edmondia *subtruncata*, Linwood and Lansing.

Nucula *parva*, Lansing.
Pinna *peracuta*, Lansing.
subspatulata, Lansing.

GASTEROPODA.

Pleurotomaria *tabulata*, Lansing.

CEPHALOPODA.

Orthoceras *rushense*, Lansing.

ARTHROPODA.

Phillipsia *major*, Lenape and Linwood.

REMARKS.—Fine specimens of *cordiates* and other plants were taken years ago from the coal-shaft at Lansing while sinking it. All the fossils of the western parts of Johnson and Wyandotte counties may reasonably be looked for in this county. Detailed lists of the fossils peculiar to each individual stratum are to be found in chapter II.

LINN COUNTY.

CŒLENTERATA.

Axophyllum *rudis*, La Cygne.
Cyathaxonia *distorta*, La Cygne.
Lophophyllum *proliferum*, La Cygne.

ECHINODERMATA.

Archæocidaris ——, La Cygne.
Zeacrinus *acanthophorus*, La Cygne.
mucrospinus, La Cygne.

MOLLUSCA.

BRYOZOA.

Fenestella ——, La Cygne.
Fistulipora *nodulifera*, La Cygne.
Rhombopora *lepidodendroides*, La Cygne.
Synocladia *biserialis*, La Cygne.

BRACHIOPODA.

Athyris *subtilita*, La Cygne.
Chonetes *granulifera*, La Cygne.
verneuiliana, La Cygne.
Orthis (carbonaria) *pecosi*, La Cygne.
Productus *costatus*, La Cygne.
longispinus, La Cygne.
prattenianus, La Cygne.
punctatus, La Cygne.
Retzia *mormoni*, La Cygne.
Spirifera *camerata*, La Cygne.
lineata, La Cygne.
plano-convexus, La Cygne.
Spiriferina *kentuckiensis*, La Cygne.

GASTEROPODA.

Bellerophon *crassus*, Boicourt.

REMARKS.—All the fossils of Bourbon county may be looked for in this county, and especially those of the Erie limestone system.

LYON COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Emporia.

MOLLUSCA.

BRYOZOA.

Rhombopora *lepidodendroides*, Hartford.

BRACHIOPODA.

Athyris *subtilita*.
Rhynchonella *uta*, Emporia.
Spirifera *plano-convexus*, Emporia.

LAMELLIBRANCHIATA.

Allorisma *subcuniata*, Emporia.

Nucula *parva*, Emporia.
ventricosa.
Nuculana *bellistriata*, Emporia.

GASTEROPODA.

Bellerophon *carbonarius*, Emporia.
Marcrocheilus ——— sp., Emporia.
Naticopsis *nana*, Emporia.
Pleurotomaria *tabulata*, Emporia.
——— sp., Emporia.

CEPHALOPODA.

Goneatites *planorbiformis*, Emporia.

REMARKS.—The above is a very meager list from a county which undoubtedly will yield all the fossils of the upper Coal Measures found in Shawnee or Wabaunsee counties.

MIAMI COUNTY.

CŒLENTERATA.

Axophyllnm *rudis*, Fontana.
Cyathaxonia *distorta*, Fontana.
Lophophyllum *proliferum*, Fontana.

ECHINODERMATA.

Archæocidaris ——— sp., Fontana.
Scaphiocrinus *hemisphericus*, Fontana.
Zeacrinus *acanthophorus*, Fontana.
mucrospinus, Fontana.

MOLLUSCA.

BRYOZOA.

Chætetes *milleporaceus*, Fontana.
Fenestella ——— sp., Fontana and Paola.
Fistulipora *nodulifera*, Fontana and Paola.
Rhombopora *lepidodendroides*, Fontana.
Synocladia *biserialis*, Fontana and Paola.

BRACHIOPODA.

Athyris *subtilita*, Fontana and Paola.
Chonetes *granulifera*, Fontana.
verneuiliana, Fontana.
——— sp., Fontana.
Orthis (*carbonaria*) *pecosi*, Fontana.
Productus *costatus*, Fontana.
longispinus, Fontana.
nebrascensis, Paola.
prattenianus, Fontana.
punctatus, Fontana.
Retzia *mormoni*, Fontana.
Spirifera *camerata*, Fontana.
lineata, Fontana.
plano-convexus, Fontana.
Spiriferina *kentuckienses*, Fontana.

CEPHALOPODA.

Nautilus *sangamonensis*, Paola.

ARTHROPODA.

Phillipsia *major*, Fontana and Paola.

REMARKS.—All fossils of the Erie system may be looked for in this county; also those of the Iola limestone and the Bethany Falls limestone of Kansas City.

MONTGOMERY COUNTY.

MOLLUSCA.

BRYOZOA.

Fenestella *shumardi*, Cherryvale.
Rhombopora *lepidodendroides*, Cherryvale.
Synocladia *biserialis*.

BRACHIOPODA.

Productus *longispinus*, Drum Creek.
Rhynchonella *uta*, Cherryvale.
(Very large) sp., Cherryvale.

LAMELLIBRANCHIATA.

Allorisma *costata*, Cherryvale.
granosa, Cherryvale.
Aviculopecten *carboniferus*, Cherryvale.

GASTEROPODA.

Bellerophon *crassus*, Drum Creek.

CEPHALOPODA.

Nautilus *planovolvis*, Cherryvale.

REMARKS.—The list from this county is short, but we are fully persuaded that many of the fossils of the Erie system, the upper section of which is so fossiliferous at Kansas City and in Bourbon county, and which is exposed across this county from north to south, must yield many more species when thoroughly explored.

MORRIS COUNTY.

MOLLUSCA.

BRYOZOA.

Fenestella *shumardi*, Dunlap.
Synocladia *biserialis*, Dunlap.

BRACHIOPODA.

Chonetes *granulifera*, Dunlap.
Meekella *striato-costata*, Dunlap.
Productus *semireticulatus*, Dunlap.
Streptorhynchus (*Hemipronites*) *crassus*, Dunlap.

REMARKS.— Undoubtedly many more fossils found in the Upper systems are common to this county.

NEOSHO COUNTY.

CŒLENTERATA.

Cyathaxonia *distorta*, Thayer.

MOLLUSCA.

BRACHIOPODA.

Athyris *subtilita*, Osage Mission.
Chonetes *mesoloba*, Osage Mission.
Spirifera *plano-convexus*, Osage Mission.

GASTEROPODA.

Bellerophon ——— sp., Osage Mission.

CEPHALOPODA.

Nautilus *occidentalis*, Thayer.

REMARKS.—The fossils of the Erie systems were found in abundance at the very borders of this county on the northeast, and undoubtedly can be found in the same profusion wherever these rocks appear, in their croppings, as they trend across this county to the southwest.

OSAGE COUNTY.

CŒLENTERATA.

Axophyllum *rudis*, Melvern.
Syringopora *multattenuata*, Melvern and Lyndon.

MOLLUSCA.

BRYOZOA.

Fenestella ——— sp., Melvern.
Stictopora ——— sp., Melvern.

BRACHIOPODA.

Athyris *subtilita*, Melvern.
Lingula *mytiloides*.
Retzia *mormoni*, Melvern.
Spirifera *camerata*, Melvern and Ridgeway.
Spiriferina *kentuckiensis*, Melvern.

LAMELLIBRANCHIATA.

Allorisma *marionensis*.
Aviculopecten *carboniferus*, Melvern.
——— sp., Melvern.
Edmondia *subplana*, Melvern.
Streptorhynchus (*-Derbya*) *crenistriatus*, Melvern.
Nucula *parva*, Melvern.

CEPHALOPODA.

Goneatites *globosus*, Melvern.

SHAWNEE COUNTY.

PROTOZOA.

Fusulina *cylindrica*,
Tecumseh, Topeka, Sugar Works, Valencia, and Willard.
ventricosa.
Topeka.
robusta.
Willard.

CŒLENTERATA.

Cyathaxonia *distorta*.
Valencia.
Lophophyllum *proliferum* (B).
Tecumseh, Topeka, Sugar Works, and Willard.

ECHINODERMATA.

Archæocidaris ———
Topeka and Willard.
Eupachycrinus ———
Topeka.
Zeacrinus *acanthophorus*.
Topeka.
mucrospinus.
Topeka and Valencia.
Crinoid columns.
Tecumseh, Topeka, Sugar Works, Valencia, and Willard.

MOLLUSCA.

BRYOZOA.

Batostomella *interstincta* (B).
Topeka.
Chætetes *carbonarius* ?
Topeka, Valencia, and Willard.
——— sp.
Topeka.
Cyclopora ?? ——— sp. (B).
Topeka.
Fenestella *compressa* (B).
Topeka.
limitaris ? (B).
Topeka.
modesta ? (B).
Topeka.
sevillensis ? (B).
Topeka.
Lyropora ? ——— sp. (B).
Topeka.
Polypora *spininodata* (B).
Topeka.
——— sp. cf. *tuberculata* (B).
Topeka.
——— sp. (B).
Topeka.
Rhombopora *lepidodendroides*.
Topeka.
varians (B).
Topeka.

Septopora ? ——— sp. (B).
Topeka.

Stenopora *carbonaria* (B).
Topeka.

var. *confuta* (B).
Topeka.

Streblotrypa *nicklesi* (B).
Topeka.

Synocladia *biserialis*.
Topeka and Valencia.

BRACHIOPODA.

Athyris *subtilita*.
Tecumseh, Topeka, Sugar Works, Valencia and Willard.

Chonetes *glabra* (B).
Topeka.

granulifera.
Topeka and Sugar Works.

Derbya *crassa* (B).
Tecumseh and Topeka.

robusta (B).
Tecumseh and Topeka.

Discina *convexa* ? (B).
Topeka.

nitida (B).
Topeka.

Lingula *mytiloides* (B).
Tecumseh, Topeka, and Sugar Works.

umbonata ? (B).
Topeka.

Meekella *striato-costata*.
Valencia and Willard.

Orthis *keokuk* (B).
Topeka.

Productus *americanus*.
Tecumseh and Topeka.

cora (B).
Tecumseh and Topeka.

costatus.
Topeka.

longispinus.
Topeka.

nebrascensis.
Topeka.

pertenuis.
Valencia.

punctatus.
Topeka.

semireticulatus.
Valencia and Willard.

Retzia *mormoni*.
Topeka.

Rhynchonella *uta* (B).
Tecumseh, Topeka, and Sugar Works.

metallica ? (B).
Sugar Works.

Spirifera *camerata*.
Topeka, Sugar Works, and Valencia.

Spiriferina *kentuckiensis*.
Topeka.

Syntrialasma *hemiplicata*.
Topeka.

Terebratula *bovidens*.
Topeka.

LAMELLIBRANCHIATA.

Allorisma *costata* (B).
Sugar Works.

geinitzia (B).
Sugar Works.

granosa (B).
Tecumseh, Topeka, and Sugar Works.

subcuniata.
Valencia and Willard.

Avicula *longa* (B).
Topeka.

Aviculopecten *carboniferus* (B).
Topeka and Sugar Works.

coxanus (B).
Topeka and Sugar Works.

hartzeri ? (B).
Topeka and Sugar Works.

maccoyi ? (B).
Willard.

occidentalis (B).
Tecumseh, Topeka, and Sugar Works.

whitei ? (B).
Topeka and Sugar Works.

Aviculopinna *americana* (B).
Topeka.

Edmondia *aspinwallensis* (B).
Sugar Works.

nebrascensis (B).
Sugar Works.

ovata ? (B).
Topeka.

Entolium *aviculatum* (B).
Tecumseh, Topeka, Sugar Works, and Willard.

Lima *retifera* (B).
Topeka.

Macrodon *tenuistriata* (B).
Topeka.

Monoptera *mariana* (B).
Topeka.

Myalina *perattenuata* (B).
Topeka and Sugar Works.

recurvirostris.
Valencia.

subquadrata.

swallovi (B).
Tecumseh, Topeka, and Sugar Works.

Nucula *ventricosa* (B).
Topeka.

Nuculana *bellistriata* (B).
Topeka and Sugar Works.
var. *attenuata* (B).
Topeka and Sugar Works.

Pinna *subspatulata* (B).
Tecumseh.

Placunopsis *carbonaria* (B).
Topeka.

Prothyris *elegans* (B).
Topeka.

Solenomya *radiata* (B).
Topeka.

Schizodus *curtus* (B).
Tecumseh, Topeka, and Sugar Works.
curtiforme ? (B).
Tecumseh and Topeka.

GASTEROPODA.

Bellerophon *bellus* (B).
Topeka and Sugar Works.
carbonarius.
Topeka, Valencia, and Willard.
crassus.
Tecumseh and Willard.
montfortanus (B).
Sugar Works and Willard.
percarinatus (B).
Topeka and Sugar Works.

Loxonema ——— sp. (B).
Topeka.

Macrocheilus *anguliferus* (B).
Topeka and Sugar Works.
paludinæformis (B).
Topeka.
primigenius (B).
Topeka and Sugar Works.
ventricosus (B).
Topeka and Sugar Works.

Naticopsis *nana* (B).
Topeka and Sugar Works.
ventricosus (B).
Tecumseh, Topeka, and Sugar Works.
wheeleri (B).
Tecumseh.

Orthonema *subtæniata* (B).
Topeka.

Pleurotomaria *grayvillensis* (B).
Topeka.
illinoiensis (B).
Topeka.
perhumerosa (B).
Topeka.
sphærulata (B).
Topeka.
subdecussata (B).
Topeka.
tabulata.
Tecumseh.

CEPHALOPODA.

Nautilus *occidentalis* (B).
Topeka and Sugar Works.
ponderosus ?? (B).
Topeka.

ARTHROPODA.

Phillipsia *major*.
Topeka.
scitula (B).
Tecumseh, Sugar Works, Willard.

VERTEBRATA.

Petalodus *destructor* (B).
Tecumseh and Topeka.
A fish tooth.
Topeka.

WABAUNSEE COUNTY.

PROTOZOA.

Fusulina *cylindrica* (P), Maple Hill, Buffalo Mound, Paxico, McFarland, and Alma.
robusta, Maple Hill.

CŒLENTERATA.

Campophyllum *torquium* (P), Buffalo Mound.

Lophophyllum *proliferum*, McFarland.

ECHINODERMATA.

Archæocidaris ——— sp. (P), Alma and McFarland.

Eupachycrinus ——— sp., McFarland.

Zeacrinus *acanthophorus*, McFarland.
mucrospinus, McFarland.

Crinoid stems and plates of head (P), Alma and McFarland.

MOLLUSCA.

BRYOZOA.

Chætetes *carbonarius* ? McFarland.
——— sp. (P), McFarland.
Rhombopora *lepidodendroides*, McFarland.
Synocladia *biserialis*, McFarland.

BRACHIOPODA.

Athyris *subtilita* (P), Maple Hill, Buffalo Mound, Paxico, McFarland, and Alma.
Aviculopecten *occidentalis* (P), McFarland.
Chonetes *glabra* (P), McFarland.
granulifera (P), Maple Hill, Buffalo Mound, Paxico, McFarland, and Alma.
verneuiliana (P), Buffalo Mound.
Derbya *crassa* ? (P), McFarland and Alma.
Discina *nitida* (P), McFarland.
Meekella *striato-costata* (P), Buffalo Mound, McFarland, and Alma.
Productus *cora*, (P), McFarland.
longispinus (P), Buffalo Mound and McFarland.
nebrascensis (P), McFarland and Alma.
semireticulatus (P), Buffalo Mound, McFarland and Alma.
symmetricus (P), McFarland.
Hustedia (*retzia*) *mormoni*, McFarland.
Rhynchonella *uta* (P), Buffalo Mound and McFarland.
Spirifer *cameratus* (P), Buffalo Mound and McFarland.
plano-convexus (P), Buffalo Mound and McFarland.
Spiriferina *kentuckiensis* (P), McFarland.
Syntrialasma *hemiplicata* (P), McFarland and Alma.
Terebratula *bovidens* (P), McFarland.

LAMELLIBRANCHIATA.

Allorisma *geinitzia* (P), Buffalo Mound.
subcuneata (P), McFarland.
Pinna *peracuta* (P), Buffalo Mound.
Myalina *subquadrata* (P), McFarland.
Pseudomonotis *hawni* (P), Alma.

GASTEROPODA.

Straparollus (*buomphalus*) *subrugosus*.

ARTHROPODA.

Phillipsia *scitula* (P), Buffalo Mound and McFarland.

REMARKS.—When doing the stratigraphic work of the Kansas river section, chapter VI, the time was so limited while in this county that but little attention could be given to the fossil fauna. Since then, the paper, by Prof. Charles S. Prosser, on "Kansas River Section of the Permo-carboniferous and Permian Rocks of Kansas," has been received, in which is a list of fossils given as found in several places in this county, all of which have been copied and designated by the letter P. All others reported in the same columns from McFarland were gathered in less than 10 minutes' time, in an open field about a mile and a half southeast of that town, and are from the shales immediately below the important limestone, which we have described in our section as lying first below the Alma or Cottonwood Falls rock.

WILSON COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Neodesha, 11.

CŒLENTERATA.

Cyathaxonia *distorta*, Vilas.
Lophophyllum *proliferum*, Neodesha, 11.

ECHINODERMATA.

Erisocrinus *typus*, Neodesha, 11.
Zeacrinus *mucrospinus*, Neodesha, 11.

MOLLUSCA.

BRYOZOA.

Chætetes ——— sp., Neodesha, 11.
Fistulipora *nodulifera*, Fredonia.
Synocladia *biserialis*.

BRACHIOPODA.

Athyris *subtilita*, Neodesha, 11.
Chonetes *verneuiliana*, Neodesha, 11.
Derbya ——— sp., Neodesha, 11.
Orthis (*carbonaria*) *pecosi*, Neodesha, 11.
Productus *costatus*, Neodesha, 11.
longispinus, Neodesha, 11.
symmetricus, Vilas.
Retzia *mormoni*, Fredonia.
Spirifera *camerata*, Neodesha, 11.
Spiriferina *kentuckiensis*, Neodesha, 11.
Syntrialasma *hemiplicata*, Guilford and Neodesha, 11.

GASTEROPODA.

Bellerophon ——— sp., Neodesha, 11.

REMARKS.—All the fossils found in the limestones and shales between them at Iola, Allen county, may reasonably be looked for in the same formations in this county.

WOODSON COUNTY.

CŒLENTERATA.

Lophophyllum *proliferum*, Neosho Falls.

MOLLUSCA.

BRACHIOPODA.

Productus *costatus*, Neosho Falls.
Streptorhynchus *crassus*.
crenistriatus.

REMARKS.—This is a very small showing for this county, but it undoubtedly results, as in several other cases, from lack of observation, for the fossils of the Carlyle and Garnett systems undoubtedly go with these limestones into this county.

WYANDOTTE COUNTY.

PROTOZOA.

Fusulina *cylindrica*, Edwardsville, 11.

CŒLENTERATA.

Axophyllum *rudis*, Kansas City and Pomeroy, 11, 22.
Campophyllum *torquium*, Kansas City and Pomeroy, 11, 22.
Cyathaxonia *distorta*, Kansas City and Pomeroy, 11, 22.
Lopophyllum *proliferum*, Kansas City, Edwardsville, and Pomeroy, 11, 22.
Michelinia *engeneæ*, Pomeroy, 11.
Syringopora *multattenuata*, Kansas City.

ECHINODERMATA.

Agassizocrinus *carbonarius*, Kansas City.
Archæocidaris *mucronatus*, Kansas City.
triserrata, Kansas City.
——— sp., Kansas City and Edwardsville, 11, 22.
——— sp., Kansas City.
Erisocrinus *typus*, Kansas City.
Eupachycrinus *craigi*, Kansas City.
tuberculatus, Kansas City and Edwardsville, 11, 22.
——— sp., Kansas City, 22.
Graphiocrinus ——— sp., Kansas City.
Poteriocrinus *hardinensis*, Kansas City.
Scaphiocrinus *hemisphericus*, Kansas City.
Zeacrinus *acanthoporus*, Kansas City and Pomeroy, 11, 22.
discus, Kansas City.
mucrospinus, Kansas City and Pomeroy, 11, 22.
typus, Kansas City.

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VERMES.

Serpula *incita*, Kansas City.
Spirorbis *carbonaria*, Kansas City

MOLLUSCA.

BRYOZOA.

Chætetes *carbonarius* ? Kansas City.
Fenestella ——— sp., Kansas City and Pomeroy, 11, 22.
——— sp., Kansas City, 22.
Fistulipora *nodulifera*, Kansas City, Edwardsville, and Pomeroy, 11, 22.
Glauconome *nereides*, Kansas City, 22.
Polypora *submarginata*, Kansas City, 22.
Rhombopora *lepidodendroides*, Kansas City, Edwardsville, and Pomeroy, 11, 22.
Synocladia *biserialis*, Kansas City, 22.

BRACHIOPODA.

Athyris *sublamellosa*, Kansas City, 22.
subquadrata, Kansas City.
subtilita, Kansas City, Edwardsville, Turner, and Pomeroy, 11, 12? 22.
trinuclia, Kansas City.
Chonetes *granulifera*, Kansas City.
millepunctata, Kansas City.
parva, Kansas City.
smithi, Kansas City.
verneuiliana, Kansas City.
Lingula *carbonaria*, Kansas City.
melie, Kansas City.
scotia, Pomeroy, 11.
Meekella *striato-costata*, Kansas City.
Orbiculoida ? ——— sp., 22.

Orthis (*carbonaria*) *pecosi*, Kansas City.
robusta, Kansas City.
Productus *altonensis*, Kansas City.
americanus, Kansas City, 11, 22.
cora, 22.
costatus, Kansas City, 22.
longispinus, Kansas City, 11, 22.
nebrascensis, Kansas City, Edwardsville, and Pomeroy, 11, 12 ? 22.
pertenuis, Kansas City, 11.
prattenianus, Kansas City, 22.
punctatus, Kansas City, 22.
semireticulatus ? Kansas City.
symmetricus, Kansas City, 22.
Retzia *mormoni*, Kansas City, 22.
vera ? 22.
Rhynchonella *uta*, Kansas City.
——— sp., Kansas City.
Spirifera *camerata*, Kansas City, Edwardsville, Turner, and Pomeroy, 11, 22.
lineata, Kansas City, 11.
plano-convexus, Kansas City.
Spiriferina *kentuckiensis*, Kansas City, Edwardsville, and Pomeroy, 11, 22.
——— sp., 22.
Streptorhyncus *crassus*, Kansas City.
crinistriatus, Kansas City.
Syntrialasma *hemiplicata*, Kansas City.
Terebratula *bovidens*, Kansas City, Edwardsville, and Pomeroy, 11, 22.

LAMELLIBRANCHIATA.

Allorisma *costata*, Kansas City, 22.
gilberti, Turner.
granosa, Kansas City.
pleuropistha.
reflexa, Kansas City.
regularis, Kansas City.
striata, Kansas City, 22.
subcuneata, Kansas iCty, 22.
subelegans, Kansas City.
Astartella *concentrica*, KansasCity.
gurleyi, Kansas City.
vera, Edwardsville, 11, 22.
——— sp., Kansas City.
Avicula *longa*, Kansas City, 22.
Aviculopecten *carboniferus*, Kansas City, 22.
coryanus.
coxanus, Kansas City, 22.
hartzeri, Kansas City, 22.
interlineatus, Kansas City.
maccoyi, Kansas City, 22.
occidentalis, Kansas City, 22.
providencensis, 22.
winchelli, Kansas City, 22.
——— sp., Kansas City, 22.
——— sp., Kansas City, 22.
Aviculopinna *americana*, Kansas City.
Cardiomorpha *missouriensis*, Kansas City, 22.
Chænomya *leavenworthensis*, Kansas City.
maria, Kansas City..
Conocardium *obliquam*, Kansas City, 22.
Cypricardella *oblonga*, 22.
Cypricardinia *carbonaria*, 22.
Edmondia *aspinwallensis*, Kansas City.
glabra, 22.
nebrascensis, Kansas City, 22.
ovata, Kansas City.
reflexa, Kansas City.
subplana.
subtruncata, 22.
Lima *retifera*, Kansas City, 22.
Macrodon *curtus*.
carbonarius, Kansas City, 22.
obsoletus, Kansas City, 22.
tenuistriata, Kansas City, 22.
Modiola *subeliptica*, Kansas City, 22.
Monopteria *gibbosa*, Kansas City, 22.
longispina, Kansas City and Turner, 22.
marian, Kansas City and Turner, 22.

Monotis *gregaria*, 22.
Myalina *kansasensis*, Kansas City.
perattenuata, Kansas City.
recurvirostris, Kansas City and Turner, 22.
subquadrata, Turner.
swallovi, Kansas City and Turner, 22.
Nucula *parva*, Kansas City, 22.
ventricosa, Kansas City, 22.
Nuculana *bellistriata*, Kansas City, 22.
——— sp., Kansas City.
Pinna *peracuta*, Kansas City, 22.
subspatulata, Kansas City and Argentine, 11.
Pleurophorus *angulatus*, Kansas City, 22.
oblongus, Kansas City, 22.
occidentalis, 22.
tropidophorus, 22.
Prothyris *elegans*, Kansas City, 22.
Pseudomonotis *hawni* ? 22.
——— sp., 22.
Sanguinolites *obliquus*, Kansas City.
Schizodus *curtus*, Kansas City.
rossicus ?
wheeleri, Kansas City, 22.
——— sp., Kansas City.
Solemya (*solenomya*) *radiata*.
rhomboyda, Kansas City.
Solenopsis *sclenoides*, Kansas City, 22.
——— sp.
Streblopteria ——— sp., 22.
Yoldia *stevensoni*, Kansas City, 22.
——— sp., Kansas City, 22.
A large *specimen* 5x6 in., Turner.

GASTEROPODA.

Aclis *minuta*, Kansas City.
Bellerophon *carbonarius*, Kansas City.
crassus, Kansas City.
marcouanus, Kansas City, 22.
montfortanus, Kansas City.
percarinatus, Kansas City.
stevensanus, Kansas City, 22.
textilliformis, Kansas City, 22.
tricarinatus, Kansas City.
Dawsonella *meeki* ? Kansas City.
Dentalium *meekanum*, 22.
Euomphalus *subrugosus*, Kansas City.
rugosus, Kansas City.
Loxonema *rugosum*, 22.
——— sp.
Macrocheilus *intercalaris*, Kansas City.
medialis, Kansas City.
newberryi, Turner.
primigenius, Kansas City.
——— sp., Kansas City.
Murchisonia ——— sp., Turner.
Naticopsis *altonensis*.
gigantia, Kansas City.
melanoides, Kansas City.
monolifera, 22.
nana, 22.
subovata, Kansas City.
ventricosa, 22.
wheeleri, 22.
Platyceras *nebrascense*, Kansas City.
Pleurotomaria *bonharborensis*, Turner, 22.
broadheadi, Kansas City.
carbonaria, Kansas City.
coniformis, Turner, 22.
coxana, Kansas City, 22.
depressa, Kansas City.
grayvillensis, 22.
haydenana, Kansas City.
inornata, Kansas City, 22.
marcouana, Turner.
newportensis, Kansas City.
perhumerosa, Kansas City.
speciosa, 22.
sphærulata, 22.
subdecussata, Kansas City.
tabulata, Kansas City.
tumida, Kansas City.
turbiniformis, 22.
valvatiformis ? Kansas City.
——— sp., Kansas City, 22.
Polyphemopsis *nitidula*, Kansas City, 22.
inornata, Kansas City, 22.
peracuta, Kansas City.

Pupa *vitusta*, Kansas City?
Straparollus *planorbis*, Kansas City.
planispirus, Kansas City.
subrugosus, Kansas City.
umbilicatus, Kansas City.
——— sp., Kansas City.
Trachydomia *nodosum*, 22.
hollidayi, Kansas City.
Turritella (*accilisina*) *stevensana*, 22.
Conularia (a *Pteropod*) *crustula*.
——— sp., 22.

CEPHALOPODA.

Cyrtoceras ——— sp., Turner.
Goneatites *lyoni*, Kansas City.
——— sp. ?
——— sp. ? Kansas City and Turner.
Nautilus ? *capax*.
ferratus, 22.
globatus, Kansas City.
lasellensis, Kansas City.
missouriensis, 22.
Nautilus ? *occidentalis*.
planorbiformis, Kansas City.
planovolvis.
ponderosus, Turner.
sangamonensis, 22.
todanus, Kansas City, 22.
——— sp., 22.
Orthoceras *munstrianum*, Kansas City.
rushense, 22.

ARTHROPODA.

Phillipsia *major*, Kansas City and Pomeroy, 11, 22.
scitula, Kansas City, 22.

VERTEBRATA.

Peripristis *clenoptychus*, Kansas City.
Petalodus *destructor*, Kansas City, 22.
semicircularis, Kansas City.
Petrodus *occidentalis*, Kansas City.
A fish tooth, Edwardsville.

Remarks.—Many of the fossils, it will be seen, are simply reported from Kansas City without reference to any particular stratum. Of these the greater number were gathered during a series of years without any regard to their stratigraphic position, and therefore the exact horizon is not known. Many were secured by the State University by purchase, and were labeled simply as obtained at Kansas City. My own private collection was largely made there and labeled as coming from there, and it is only where memory serves me well that the strata from whence the fossils were taken is given. Fossils from the oolitic stratum have certain lithologic characteristics in the adhering limestone by which their locality can never be mistaken. The fossils reported from Edwardsville are from the equivalent of the Iola limestone of Kansas City; those of Turner from the black chert limestone and oolitic strata. Those from Pomeroy are from the same systems as at Edwardsville. Some fossils of the Coal Measures have been reported from Sumner, Riley, Geary and other counties along the Permo-carboniferous areas of the state, but they are few, except those from Riley county, as reported by Swallow, Prosser, and others. No tables, therefore, are given, but for further information see chapter VI, on the Kansas river section.

Some few counties north of the Kansas river have been given a place in this chapter, but Doniphan county does not appear in the tabulation. For the fossils found in said county during the Survey, see chapter II, on the Missouri river section.

GENERAL REMARKS.

With a few exceptions, all the organic remains herein enumerated are to be found in the museum of the State University, that institution having secured them either by purchase, or through the labors of its collectors. Kansas itself has furnished no little share of that excellent collection; and Mesozoic as well as Paleozoic specimens are to be found there. It contains some of the rarest specimens in the country.

It will be seen that much more has been reported from some counties than others; but this must not be taken as an indication that in some counties the organic remains are fewer in the number of genera and species than in others. This may result only from the fact that we have been able to give closer observation to the rocks of the counties in which the tables are fuller. Wyandotte county, for example, has had months, where others, such as Wilson and Woodson or Greenwood, have had but hours. This explanation will hold good in the case of Bourbon county, where I have made my home for the past four years. The neighborhood of Kansas City has had many observers, as well as the spare moments of eleven busy years during my residence there. Many of the counties, such as Greenwood, Elk, Wabaunsee, Jefferson, etc., we are fully persuaded, which have but short lists, are rich in fossils. We must also have railroad cuts or quarries in order to find specimens in quantities and a state of preservation suitable for their identification, and, from the nature of things, such places are limited.

The Mississippian rocks only appear in a small district in the extreme southeastern corner of the state, in Cherokee county, the fossils of which are of the Keokuk and Chester types. The fossils here are mainly casts, especially in the chert formations, and therefore difficult to identify. The limestones are largely made up of crinoid fragments, but so triturated and crystalized that but few specimens can be taken, except in upper layers along Spring river. Many of the cavities in the chert made by the carrying away of the calcareous portions of the fossils, whether corals, crinoids, or mollusks, have been lined by the common minerals of lead or zinc of the region.

The lower Coal Measures are characterized by their abundance of certain species which either do not appear above, or if they do, become much more rare. For instance, the little Brachiopod *Chonetes mesoloba* has not thus far, to my knowledge, been found above the Bethany Falls limestone of Broadhead, which corresponds with the lower member of the Erie system of Bourbon county. And the *Discina nitida*, while it abounds in the lower formations, is a very rare fossil above the same Erie system. *Chonetes granulifera* is rare and small in lower strata but very abundant and very large in the upper strata, and especially in the immediate neighborhood of the Cottonwood Falls limestone. *Meekella striato-costata*, while it ranges all the way from the lower limestones of the Coal Measures upwards, is found more abundant above, but of gigantic proportions in the lowest important limestone of the series — the Fort Scott cement. *Fusulina* is very rare in the lower strata, but abounds in the upper, some layers

being almost literally made up of this little rhizopod. The Echinodermata — family Archæocidaris — begin in the lower limestones, abound in the region of the Topeka limestones, but decrease in numbers in the higher formations; although increasing in robust forms.

Among the Bryozoans, *Chætetes* abounds in very large masses in the lower, but is represented by small forms in the upper rocks. In its ramose forms it does not vary much in the entire range of rocks in size or quantity. Enormous Crinoid columns are found in the cement limestone of Bourbon county, and no limestone in the whole series is destitute of the exuviæ of the Crinoidea, although in no other are they even approximately so large. The only Pteropod fossil, so far observed, is the genus *Conularia*, one species of which — *Conularia crustula* — has only been found until recently in a thin calcareous clay, not over eight inches thick, in the Kansas City series, near the middle. Although most abundant in this clay in the bluffs of Kansas City, it is to be found in the same geologic horizon as far west on the Kansas river as Cedar Junction, where it disappears in the common westerly dip. During the past summer, however, it was discovered in the bituminous concretions which abound in the shales below the cement rock in Bourbon county. The characteristic Coal Measure fossil, *Athyris subtilita*, like the Crinoidea, is found in every limestone. *Syntrialasma hemiplicata* is very rare except in the lower Garnett limestone found at Ottawa, Eudora, Linwood, and north of Olathe. In this it abounds and is found in excellent preservation, especially at Eudora. The genus *Goneatites* is very rare, but found in the whole series.

The richest of all the strata in the abundance and species of its fauna is the oolitic stratum of Wyandotte county. Over 100 species have been found in it; and a strange feature of this intensely interesting rock is the fact that it contains types which might be looked upon as Permian — such as *Pseudomonotis hawni?* of the *Aviculidæ* family, and some of the *Aviculopectens* of the *Pectenidæ* family.

The general summary of the invertebrate fauna is as follows:

Protozoa	3 species.
Cœlenterata	8 "
Echinodermata	20 "
Vermes	2 "
Mollusca	224 "
Arthropoda	6 "
Total	263 species.

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PLATE I.

By Geo. I. Adams; to accompany Chapter I.

A Geologic Section along the south side of the state from Galena to Winfield.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The surface contours are taken partly from railroad levels and partly from the United States Geological Survey Topographic sheets.

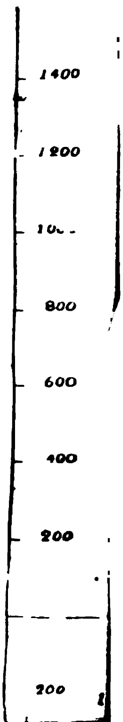

1400
1200
800
600
400
200
200

PLATE II.

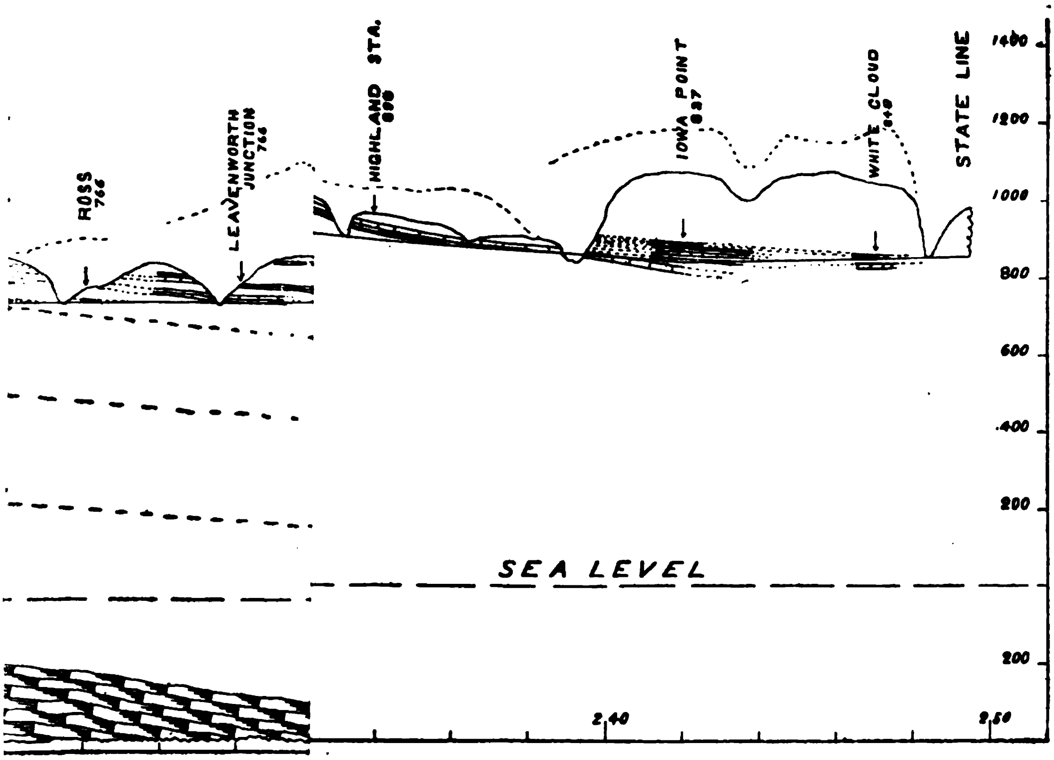
By Haworth and Bennett; to accompany Chapter II.

A Geologic Section extending near the east side of the state along the Kansas City, Fort Scott & Memphis railway from Baxter Springs to Kansas City, and from Kansas City along the west bank of the Missouri river to the north side of the state.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The surface contours are taken partly from railroad levels and partly from the United States Geological Survey Topographic sheets.



ROSS
766
LEAVENWORTH
JUNCTION
764
HIGHLAND STA.
IOWA POINT
WHITE CLOUD
STATE LINE
1400
1200
1000
800
600
400
200
SEA LEVEL
200
2,40
2,50

PLATE III.

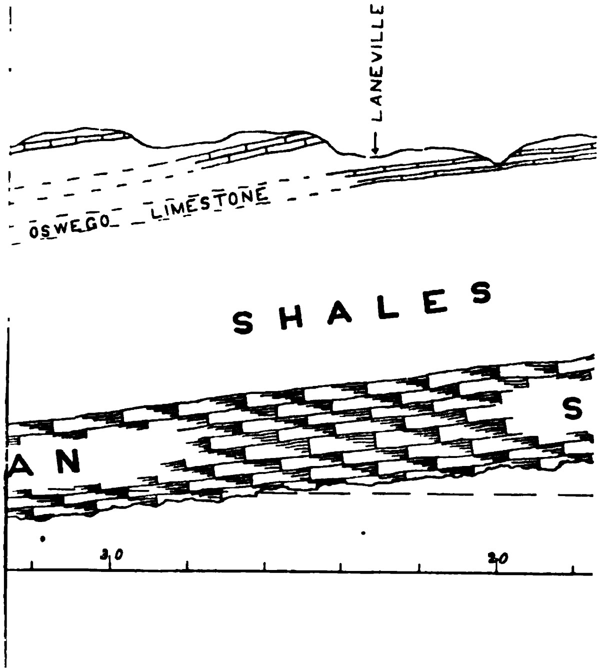
By M. Z. Kirk; to accompany Chapter III.

A Geologic Section along the Neosho river from the south line of the state to Council Grove, and along the Cottonwood river from Wyckoff to Cedar Grove.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The contours of this section are principally taken from the United States Geological Survey Topographic sheets, the part along the Cottonwood river being taken from the level of the Atchison, Topeka & Santa Fe railway track.



LANEVILLE
OSWEGO LIMESTONE
SHALES
S
AN
30
20

PLATE IV.

By John Bennett; to accompany Chapter IV.

A Geologic Section principally along the Missouri Pacific railway from the state line east of Fort Scott to Yates Center.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The contours are taken from the Missouri Pacific railway track and from the United States Geological Survey Topographic sheets.

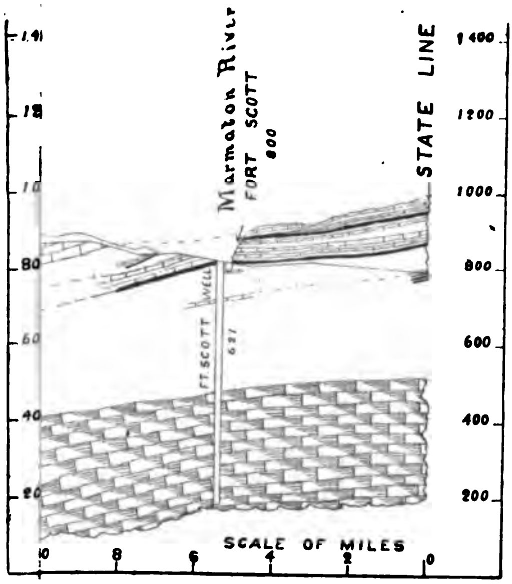

Marmaton River
FORT SCOTT
800
STATE LINE
FT. SCOTT WELL
621
1400
1200
1000
800
600
400
200
SCALE OF MILES
10
8
6
4
2
0

PLATE I.

By Geo. I. Adams; to accompany Chapter I.

A Geologic Section along the south side of the state from Galena to Winfield.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The surface contours are taken partly from railroad levels and partly from the United States Geological Survey Topographic sheets.

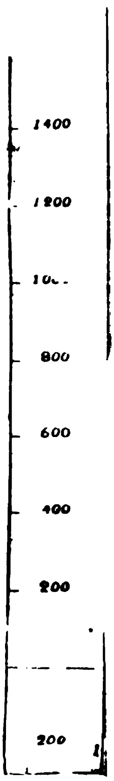

1400
1200
800
600
400
200
200

PLATE II.

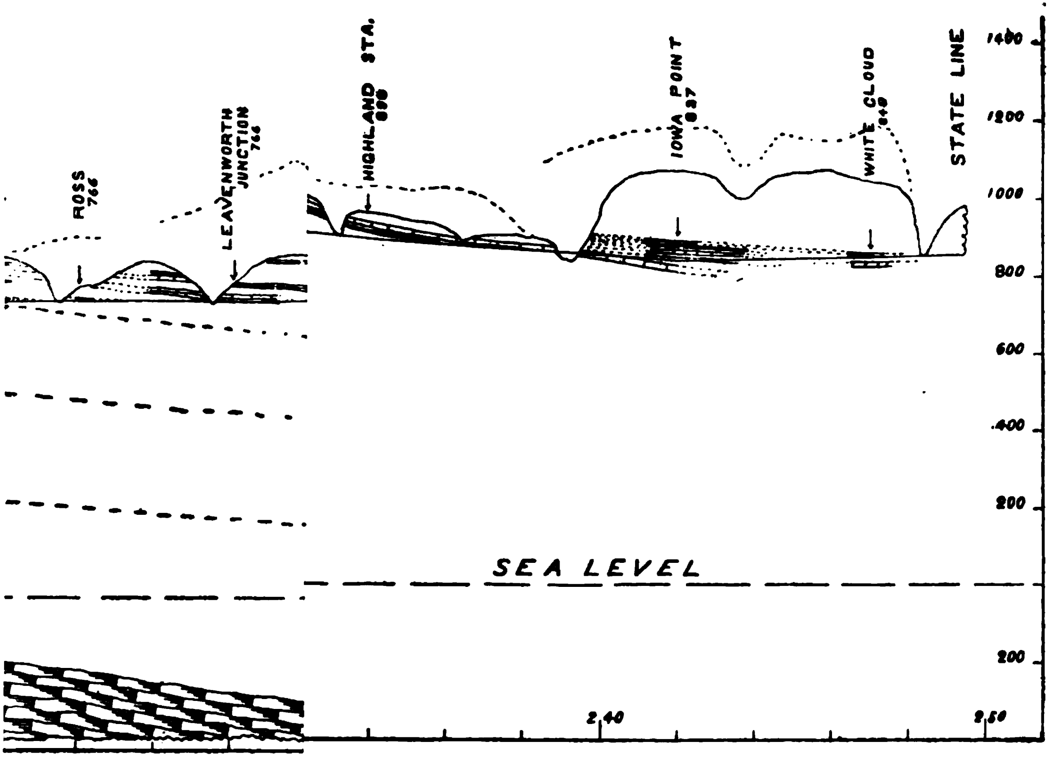
By Haworth and Bennett; to accompany Chapter II.

A Geologic Section extending near the east side of the state along the Kansas City, Fort Scott & Memphis railway from Baxter Springs to Kansas City, and from Kansas City along the west bank of the Missouri river to the north side of the state.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The surface contours are taken partly from railroad levels and partly from the United States Geological Survey Topographic sheets.



ROSS
766
LEAVENWORTH
JUNCTION
766
HIGHLAND STA.
IOWA POINT
WHITE CLOUD
STATE LINE
1400
1200
1000
800
600
400
200
SEA LEVEL
200
2,40
2,50

PLATE III.

By M. Z. Kirk; to accompany Chapter III.

A Geologic Section along the Neosho river from the south line of the state to Council Grove, and along the Cottonwood river from Wyckoff to Cedar Grove.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The contours of this section are principally taken from the United States Geological Survey Topographic sheets, the part along the Cottonwood river being taken from the level of the Atchison, Topeka & Santa Fe railway track.

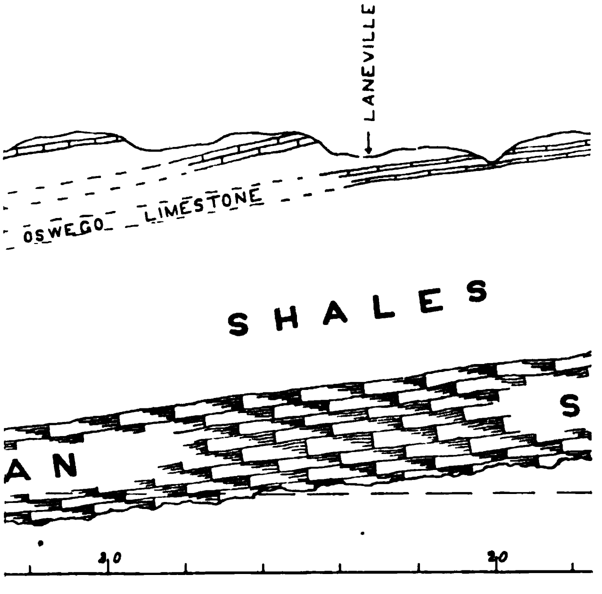

LANEVILLE
OSWEGO LIMESTONE
SHALES
S
AN
20
20

PLATE V.

By John G. Hall; to accompany Chapter V.

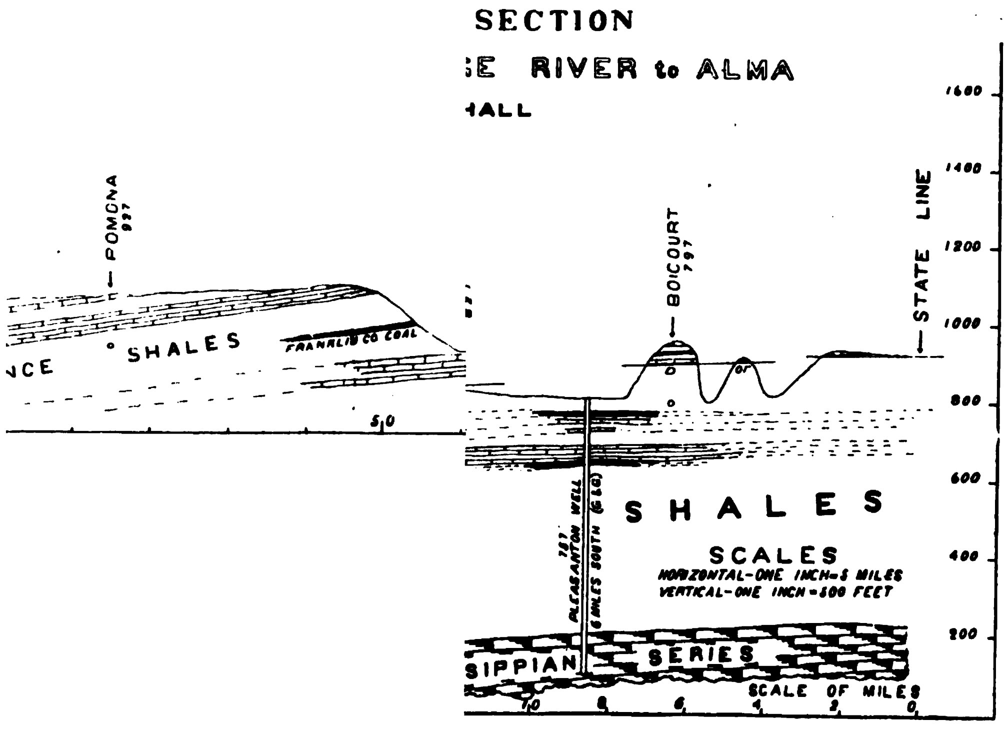
A Geologic Section principally along the Osage river from the east line of the state to Alma.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The contours are almost entirely taken from the United States Geological Survey Topographic sheets.

'LATE V.



ogical Survey of Kansas. Vol. 1.

PLATE VI.

By Bennett and Adams; to accompany Chapter VI.

A Geologic Section along the Kansas river and the Smoky Hill river from Kansas City to Abilene.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by the conventional masonry. The shales and sandstones are left bare.

The contours are principally those of the Atchison, Topeka & Santa Fe railway, the Chicago, Rock Island & Pacific railway, and the Union Pacific railway.

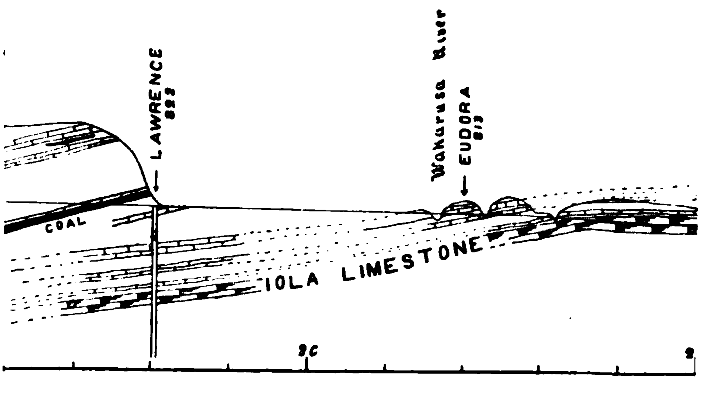

LAWRENCE
Wakarusa River
EUDORA
COAL
IOLA LIMESTONE

PLATE VII.

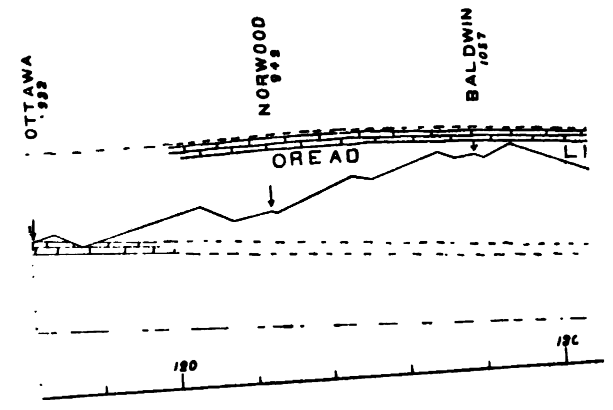
By Erasmus Haworth; to accompany Chapter VII.

A Geologic Section from Coffeyville to Lawrence along the line of the Atchison, Topeka & Santa Fe railway.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by conventional masonry. The shales and sandstones are left bare.

The contours are those of the railroad track.



OTTAWA
NORWOOD
BALDWIN
1057
OREAD
120

PLATE VII.

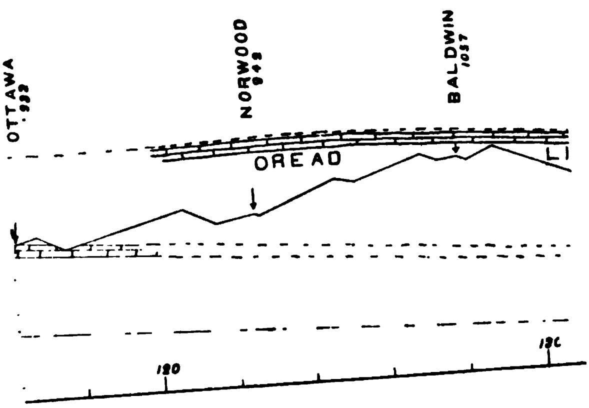
By Erasmus Haworth; to accompany Chapter VII.

A Geologic Section from Coffeyville to Lawrence along the line of the Atchison, Topeka & Santa Fe railway.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by conventional masonry. The shales and sandstones are left bare.

The contours are those of the railroad track.



OTTAWA
NORWOOD
BALDWIN
1057
OREAD
LI
120

PLATE VIII.

By E. B. Knerr; to accompany Chapter VIII.

A Geologic Section from Atchison to Barnes, along the Central Branch of the Missouri Pacific railway.

Scale: Vertical, 1 inch equals 500 feet; horizontal, 1 inch equals 5 miles.

The limestones are represented by conventional masonry. The shales and sandstones are left bare.

Contours are the levels of the railway track.

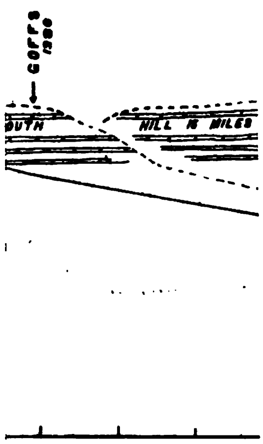

GOFFS
OUTH
HILL
MILES

PLATE IX.

By Geo. I. Adams; to accompany Chapter I.

A Topographic Map showing the elevations in the Flint Hills area, copied from the United States Geological Survey Topographic sheets.

Contour interval 250 feet.

The streams and towns in adjoining territory are given to assist the reader in a proper orientation of the Flint Hills.

PLATE IX.

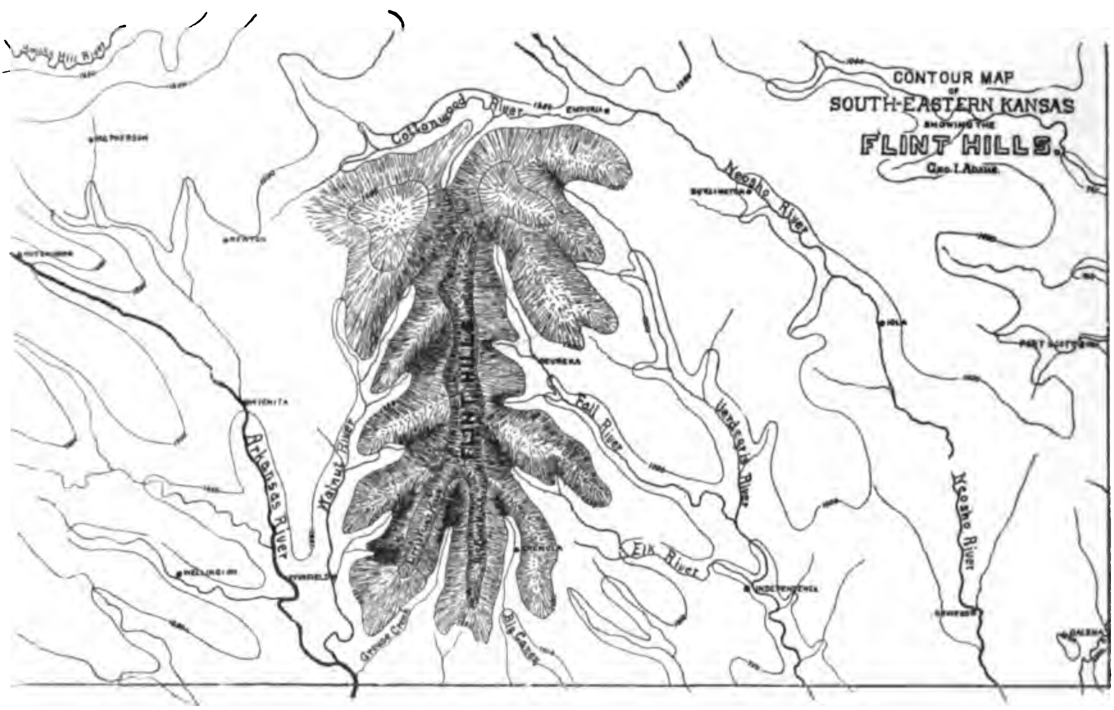

CONTOUR MAP
OF
SOUTH-EASTERN KANSAS
SHOWING THE
FLINT HILLS.
FLINT HILLS
Cottonwood River
Neosho River
Arkansas River
Walnut River
Fall River
Verdegris River
Elk River
Neosho River
Grouse Creek
Big Caney
EMPORIA
EUREKA

PLATE X.

FIGURE 1.—The Oswego Well.

It represents the two Oswego limestones near the surface with the heavy Cherokee shales for the next 450 feet or more, in which are a number of thin and unimportant limestone beds interstratified with the shale, and also ten or more thin seams of coal. At the base of the well the Mississippian limestone was reached.

Scale: Vertical, 1 inch equals 100 feet.

Record obtained through the kindness of Dr. Newlon, of Oswego, Kas.

FIGURE 2.—The Mound Valley Well.

It will be noticed that near the surface three relatively heavy limestone masses occur, below which are the Pleasanton shales and other limestones, the lower ones of which correspond well with the Oswego limestone, as can be seen by a glance at Plate I. Below these we find 427 feet of the Cherokee shales without their base being reached.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled by L. C. Crossman, Joplin, Mo.

PLATE X.

Figure 1.

OSWEGO WELL

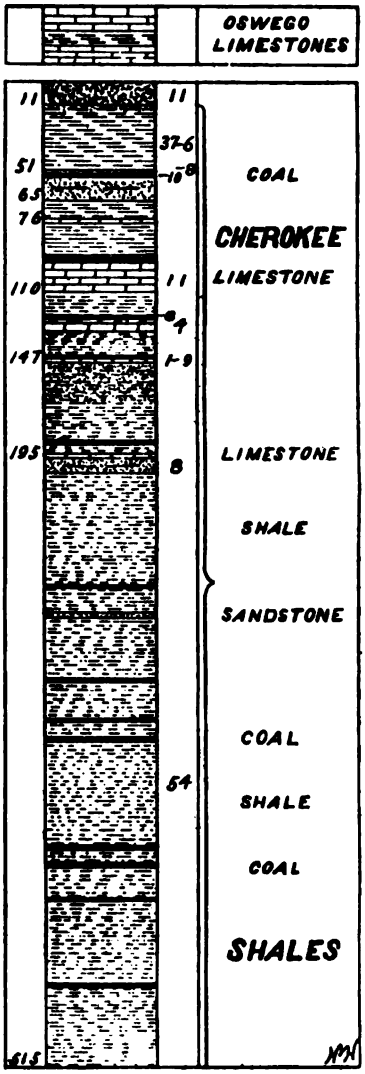


Figure 2.

MOUND VALLEY WELL

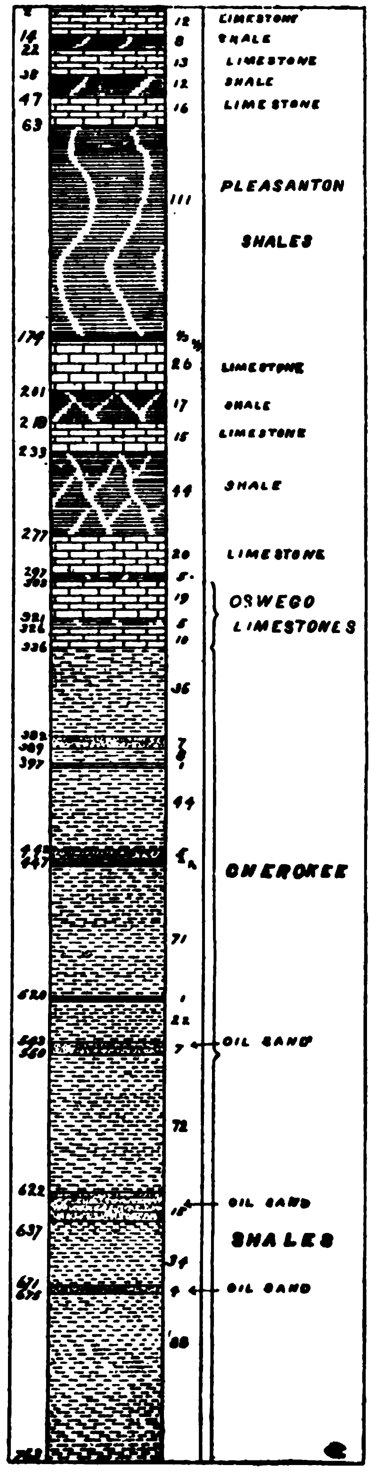


PLATE X

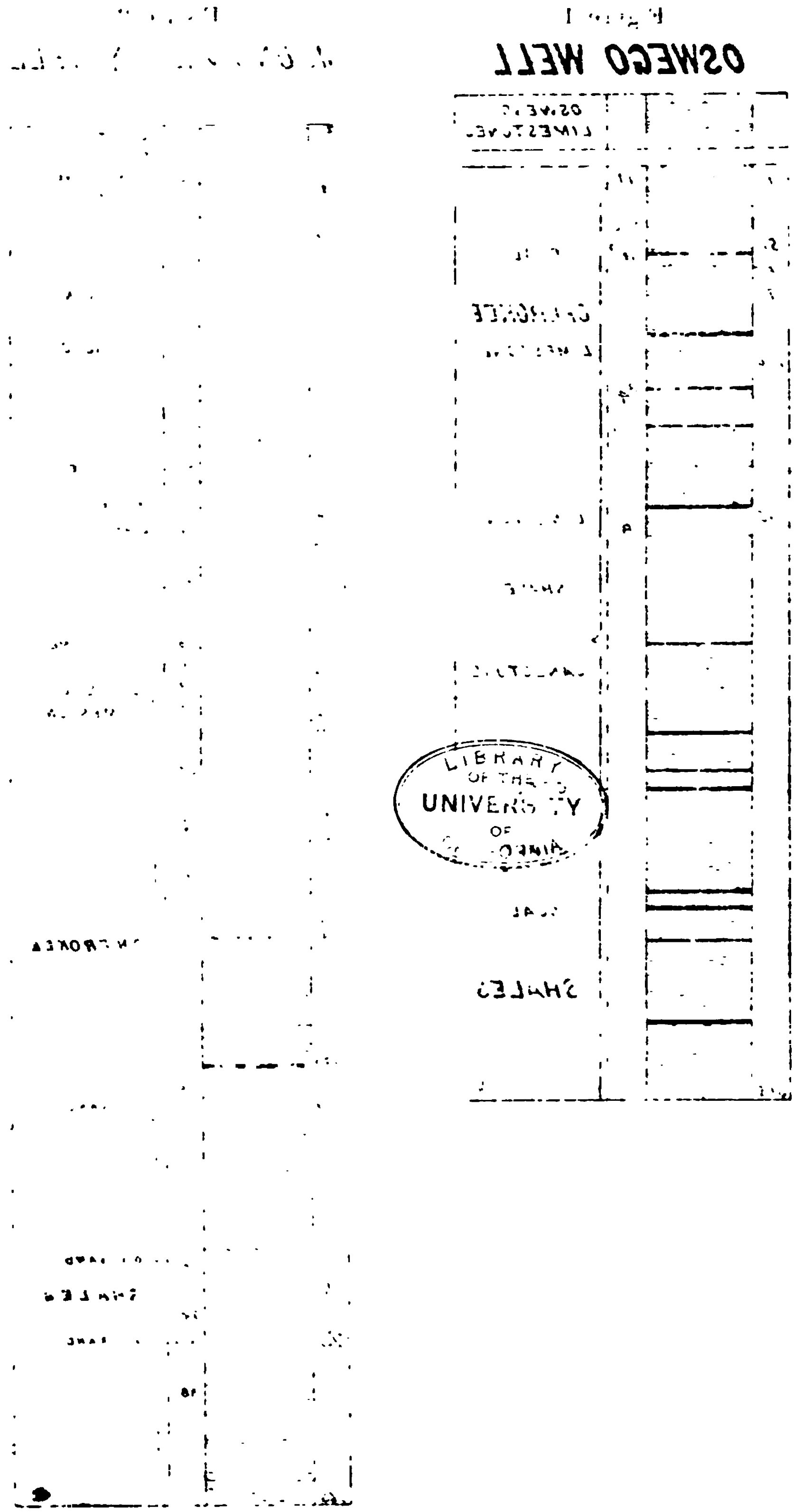


PLATE XI.

FIGURE 1.—The Cherryvale Well.

This well was made by a diamond drill which produced a two-inch core, and consequently the record is believed to be unusually accurate, even to the minute details. It will be noticed that the limestones above the Cherokee shales correspond very well with those in the Mound Valley well, Figure 2, Plate X, and that the Cherokee shales are over 400 feet thick, the Mississippian formation being reached at 1,008 feet. The well is located in the southern suburbs of Cherryvale in the angle between the two lines of the Santa Fe railway.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of the city of Cherryvale and record copied from city clerk's books, and afterwards verified by a careful examination of the well core.

FIGURE 2.—The Neodesha Well.

The interesting features of this well are the relatively heavy limestones near the top, being 68, 80, and 50 feet respectively. The depth at which the Mississippian limestone was reached was 1,063 feet. As the well was drilled with the "churn" drill and the sand pump was used only once in five feet, it is quite probable that thin intervening shale beds exist in the heavy limestones above referred to. The Cherokee shales here are over 425 feet thick.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

PLATE XI.

Figure 1.

CHERRYVALE WELL
Diamond Drill Core

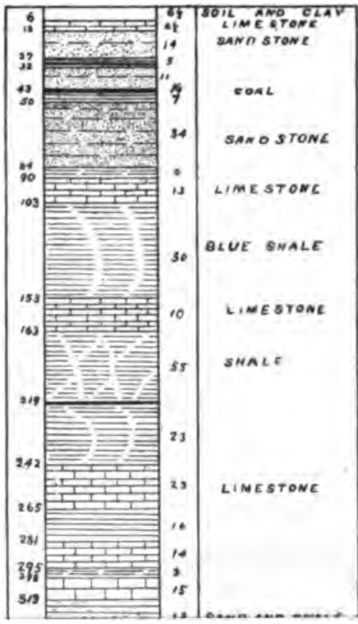


Figure 2.

NEODESHA WELL
Pierce Bro's Farm. G. & G.

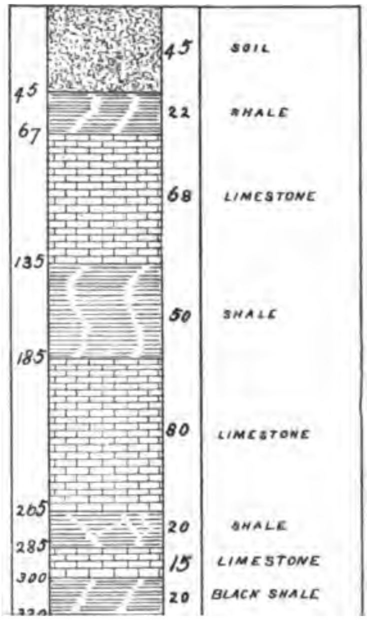


PLATE XII.

FIGURE 1.—The Niotaze Well.

The most interesting and surprising feature of this well is the great thickness of the sandstone, which reaches to a depth of 670 feet, while the first limestone is reached at a depth of 800 feet. This illustrates the existence of the heavy sandstone area lying to the west of Independence and reaching almost to the foot of the Flint Hills. Although the well is 1,158 feet deep it will be noticed that the Cherokee shales were not reached.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

FIGURE 2.—The Fredonia Well.

Beginning near the surface we have a limestone of 110 feet which evidently is the Iola limestone, below which we find the Lane shales and sandstones nearly 160 feet thick, and then the Erie limestone aggregating 172 feet. It is quite probable, however, that thin shale partings exist between the different members of the Erie limestone system. The Pleasanton shales are here 200 feet thick and the Cherokee shales 327 feet, the Mississippian limestone being reached at 1,170 feet.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

PLATE XII.

Figure 1.

NIOTAZE WELL
SEC. 17 T. 34 R. 13.

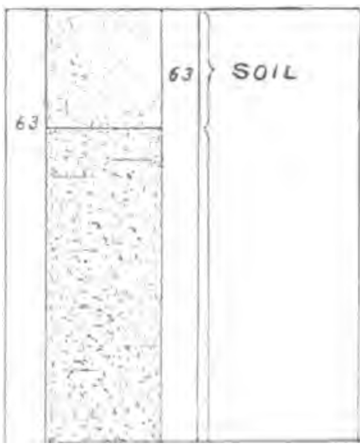


Figure 2.

FREDONIA WELL
Sec 11, T29, R. 14. G & G.

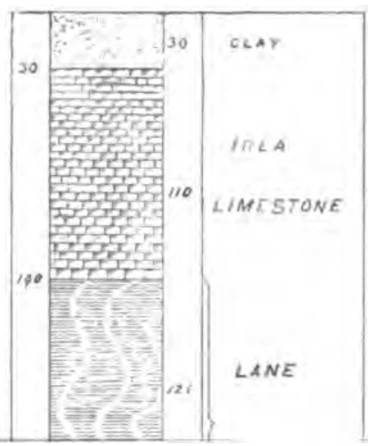


PLATE XIII.

FIGURE 1.—The Fall River Well.

This well is exceedingly interesting on account of its great depth and being so far west. We find near the surface a shale bed 173 feet thick, which doubtless is the Lane shales. Below it we have two heavy limestone beds, one 70 and the other 55 feet thick, one of which is evidentlyg the Iola limestone. But as there is a little doubt in the matter neither one has been labeled as such. Below 530 feet we have 315 feet reported as solid limestone, but it is exceedingly probable thin shale partings intervene. This distance undoubtedly represents the Erie limestone. It is particularly interesting to note that the Cherokee shales here have a thickness of nearly 375 feet.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

FIGURE 2.—The Chanute Well.

The record of this well was not given in sufficient detail near the top to show in just what condition the limestone beds exist. The 98 feet of limestone and shale and the nearly 40 feet of shales below correspond well with the Erie limestone, and the 140-foot shale bed below perhaps represents the Pleasanton shales. The Cherokee shales are here over 420 feet thick.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

PLATE XIII.

Figure 1.

Figure 2.

PLATE XIV.

FIGURE 1.—The Humboldt Well.

In this well we have the Iola limestone unmistakably represented, with the Pleasanton shales 187 feet thick, and the Cherokee shales penetrated to a distance of 335 feet without their base being reached.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record kindly furnished by them.

FIGURE 2.—The La Harpe Well.

This well is interesting on account of its showing the Iola limestone, the Thayer shales, the Erie limestones, the Pleasanton shales, and the Cherokee shales, each of which is well represented.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of the Palmer Oil Company, and record kindly furnished by Mr. Beatty for the company.

PLATE XIV.

Figure 1.

HUMBOLDT WELL

Sec. 8, T. 26, R. 18.

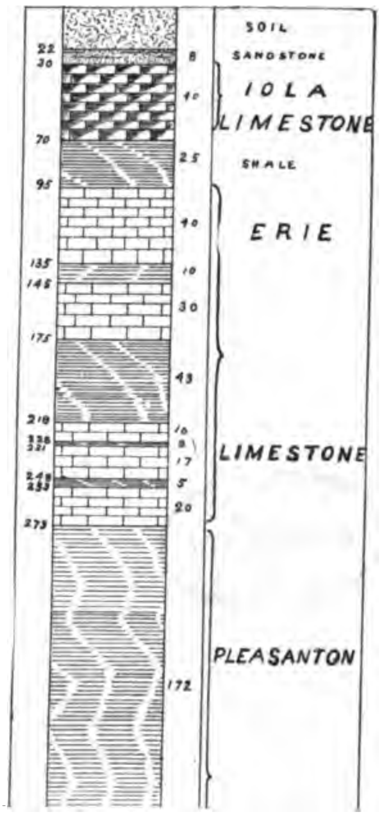


Figure 2.

LA HARPE WELL

Sec. 18, T. 24, R. 20. P.O. Co.

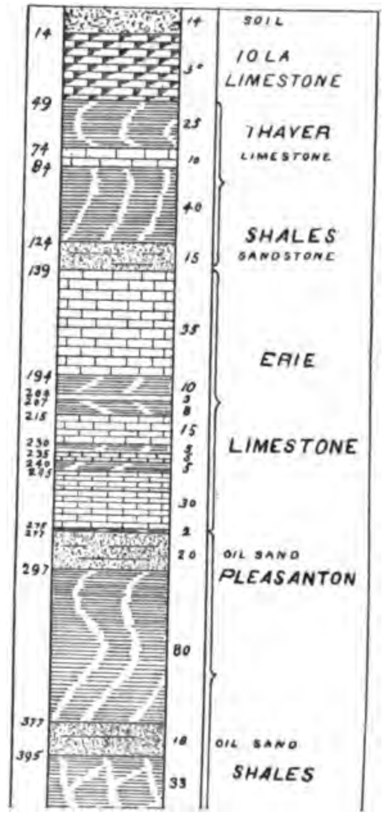


PLATE XV.

FIGURE 1.—The Iola Well.

This represents the record of the old Acers well. As the drill used was a diamond drill and a good core obtained, it is believed the record is unusually trustworthy. It will be noted that in general it corresponds very well with the La Harpe well, the main difference being a smaller amount of limestone and larger amount of shales.

Scale: Vertical, 1 inch equals 100 feet.

FIGURE 2.—The Osage Mission Well.

This well likewise was made with a diamond drill and a good core taken out. Its correspondence with other wells in the vicinity, especially the Oswego well, Figure 1, Plate X, will be noted.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of the city of Osage Mission, and record obtained from the city.

PLATE XV.

Figure 1.

IOLA WELL (ACERS

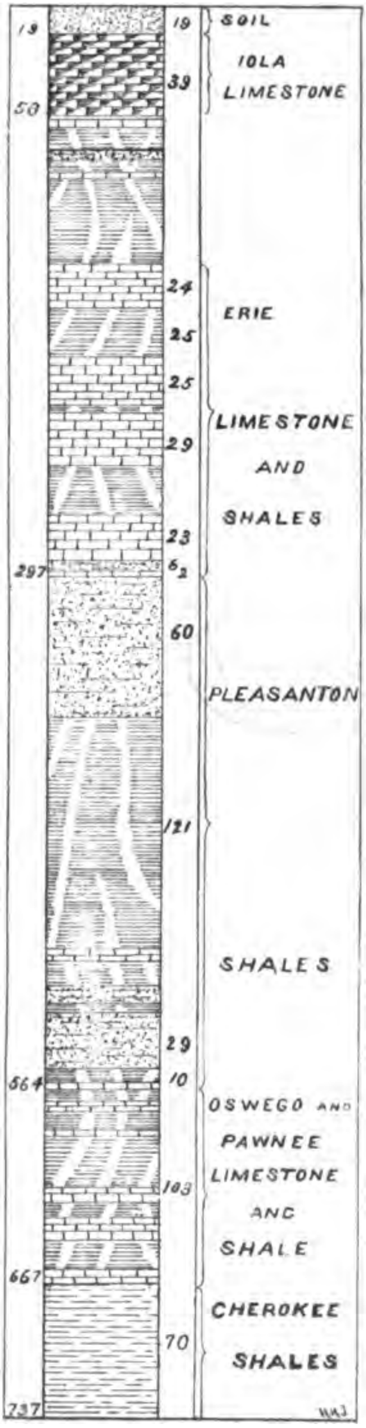


Figure 2.

OSAGE MISSION WELL

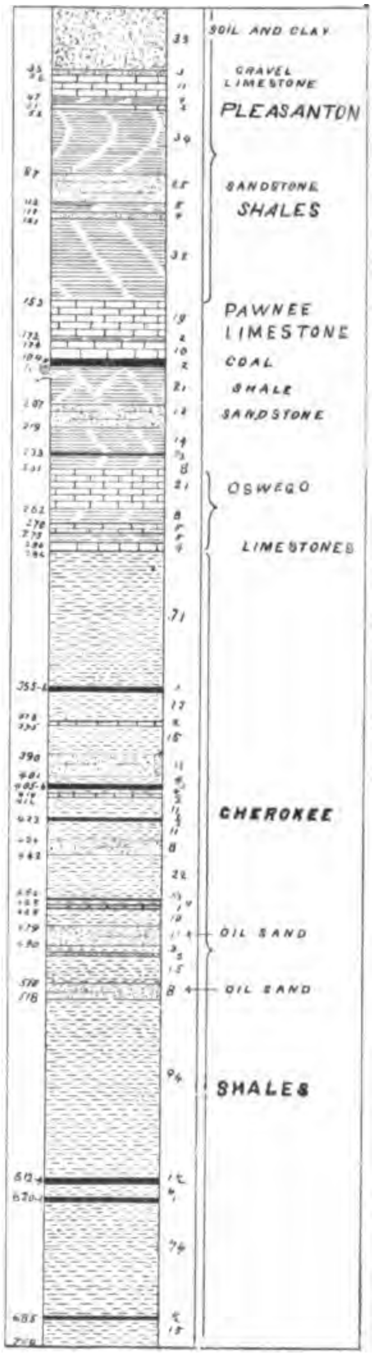


PLATE XVI.

FIGURE 1.—The Mapleton Well.

The main point of interest in this well record is an unusually heavy bed of shales below the depth of 240 feet. This corresponds with the Pleasanton shales, but it is surprising to find them so thick.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record obtained through their kindness.

FIGURE 2.—The Pleasanton Well.

This well is interesting on account of its showing the existence of the Oswego limestone this far north, and the way the Cherokee shales maintain their thickness, which is here 442 feet.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled under authority of Guffey & Galey, and record obtained through their kindness.

PLATE XVI.

Figure 1.

MAPLETON WELL
SEC. 9 T. 23 R. 20

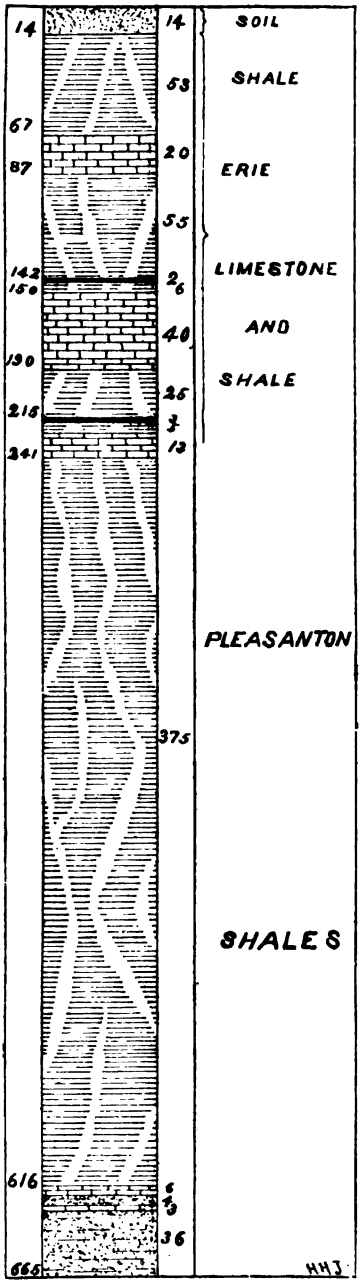


Figure 2.

PLEASANTON WELL
Sec. 25 - T. 21 R. 24 E

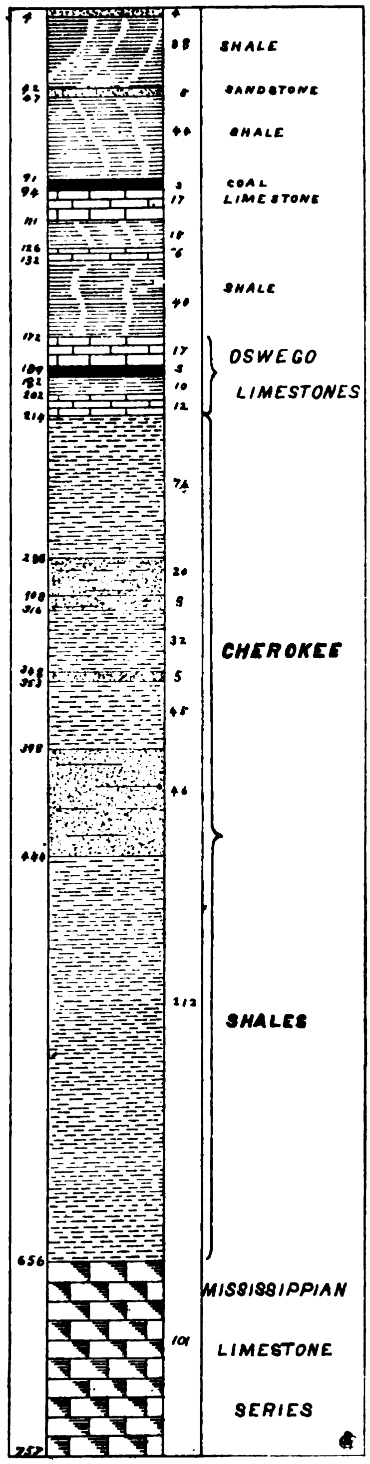


PLATE XVII.

FIGURE 1.—The Paola Well.

This well record is possibly slightly inaccurate although it is not known to be so. The unexpected feature of it is the great depth at which it represents the surface of the Mississippian limestone, 1,038 feet, which makes the Cherokee shales unusually thick, giving them a thickness of over 740 feet.

Scale: Vertical, 1 inch equals 100 feet.

Record obtained from Paola city public library.

FIGURE 2.—The Topeka Well.

This well was made with a diamond drill and an excellent core was preserved, so that we may look upon it as being unusually accurate in detail. By comparing it with Plate VI one can readily see that all of the important limestones represented along the Kansas river below Topeka pass westward and are reached by this well. The heavy bed of shales above the Iola limestone doubtless corresponds to the Lane shales, but it was thought best not to be too positive regarding the various correlations; consequently only those of unmistaken identity were correlated, the Iola limestone and the Cherokee shales.

Scale: Vertical, 1 inch equals 100 feet.

Record preserved and kindly furnished by Colonel Tweeddale, of Topeka.

PLATE XVII.

Figure 1.

PAOLA WELL.
500 ft. S. of School B'ld'g.

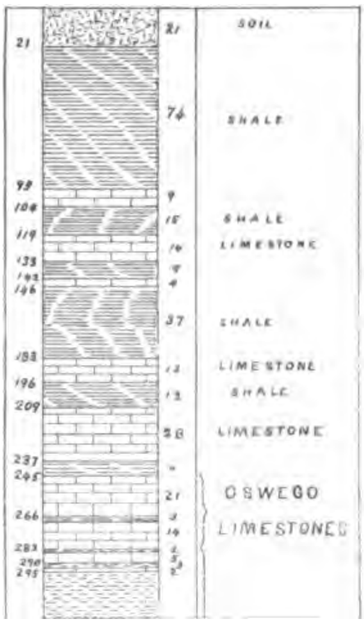


Figure 2.

TOPEKA WELL
Diamond Drill Core

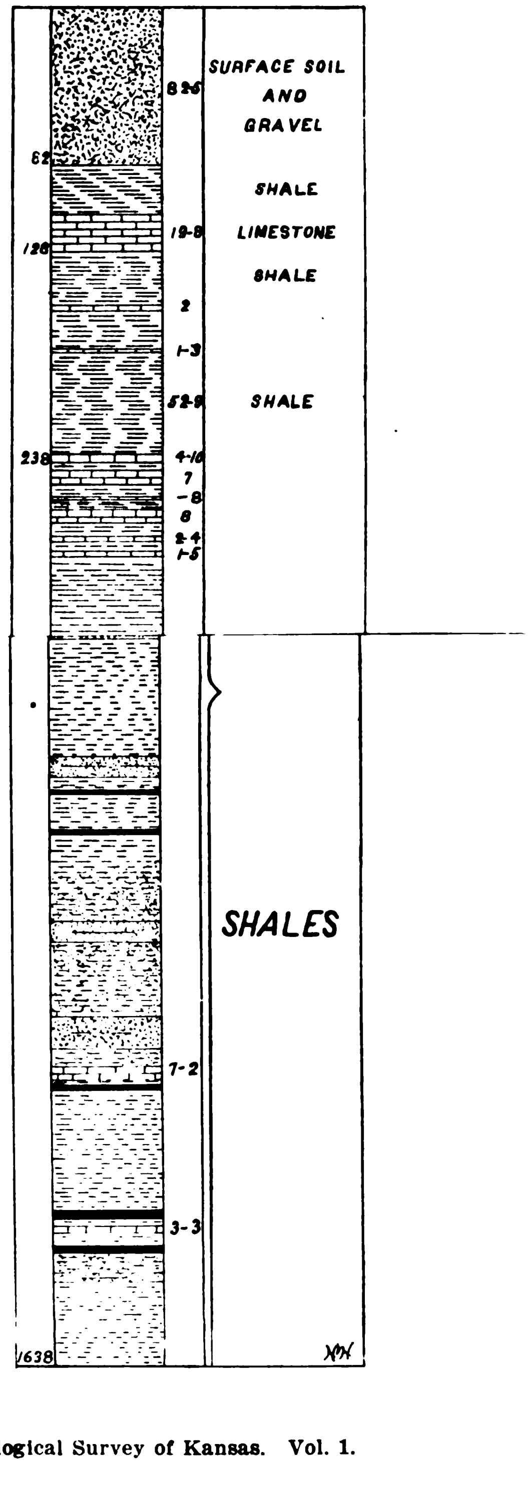


PLATE XVIII.

FIGURE 1.—The Kansas City Well.

The record of this well was copied from Broadhead, Missouri Geological Survey, 1872, Part II, page 86. As it was made with a diamond drill we may assume it is very accurate. It is interesting to note here that the Mississippian was reached at a depth of 745 feet and that the Cherokee shales are over 425 feet thick, and the Pleasanton shales nearly 200 feet thick.

Scale: Vertical, 1 inch equals 100 feet.

FIGURE 2.—The Doniphan Well.

This well is interesting on account of its corresponding so well with the surface conditions along the Missouri river above Kansas City. By reference to Plate II it will be seen that there is a close correspondence between the limestones and shales in this well and those outcropping at the various places along the surface below Doniphan.

Scale: Vertical, 1 inch equals 100 feet.

Drilled under authority of the Doniphan Coal and Mining Company, and record kindly furnished by the company.

PLATE XVIII.

Figure 1.

KANSAS CITY WELL

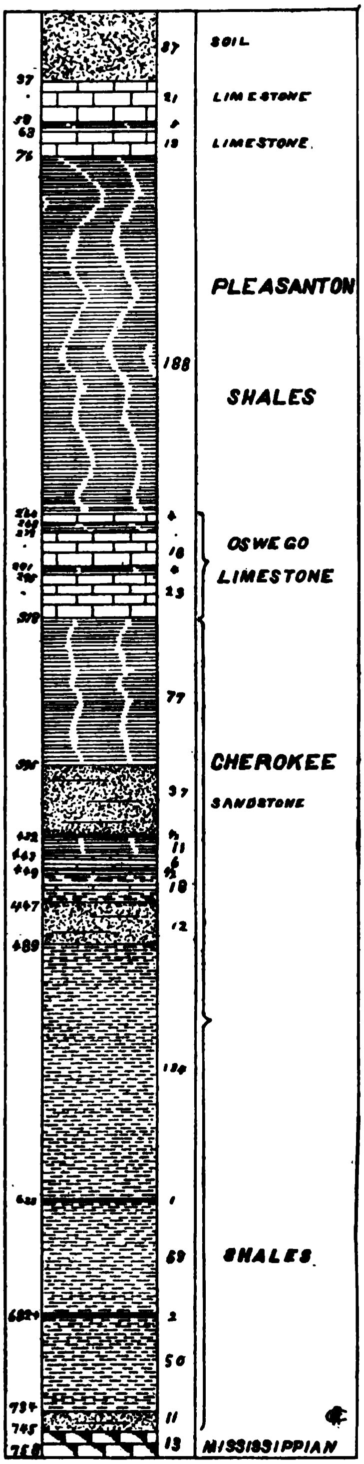


Figure 2.

DONIPHAN WELL

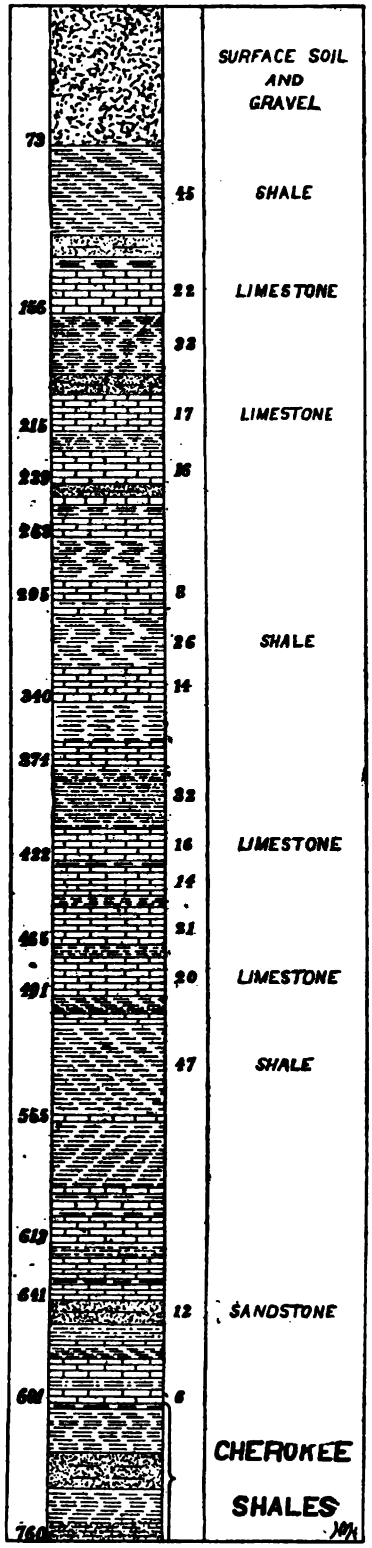


PLATE XIX.—The McFarland Well.

This is a most interesting and instructive well record, as it is located so far to the west and represents so great a depth. Being made with a diamond drill which produced a core three inches in diameter we may place great confidence in the record. It should be noted first that there is an unusually large amount of shale, reaching to a depth of 610 feet. This shows that the various limestones of the upper portion of the Coal Measures do not extend westward as far as otherwise one would have thought. Below the depth of 600 feet, however, the different limestones appear in tolerable order, none of them being as heavy as they are to the east. The conditions to the west along the Kansas river, therefore, are similar to those along the southern part of the state and beyond the Flint Hills, the limestones being replaced by great shale beds, showing that the great limestone producing area of the Carboniferous ocean was located in the eastern part of the state. It is also an interesting record, as it throws so much light on the thickness of the Coal Measures. If it has been rightly interpreted the Cherokee shales were not reached until a depth of 1,832 feet was attained. By comparing this with the Topeka well, which shows a thickness of over 700 feet for the Cherokee shales, one cannot well avoid the conclusion that the base of the Coal Measures here probably is 500 feet below the bottom of the well. As the well is known to have started about 150 feet below the Cottonwood Falls limestone, it shows tolerably conclusively that the Coal Measures are here more than 2,500 feet thick.

Scale: Vertical, 1 inch equals 100 feet.

Well drilled and record furnished by the M. C. Bullock Manufacturing Company, Chicago, Ill.

PLATE XIX.

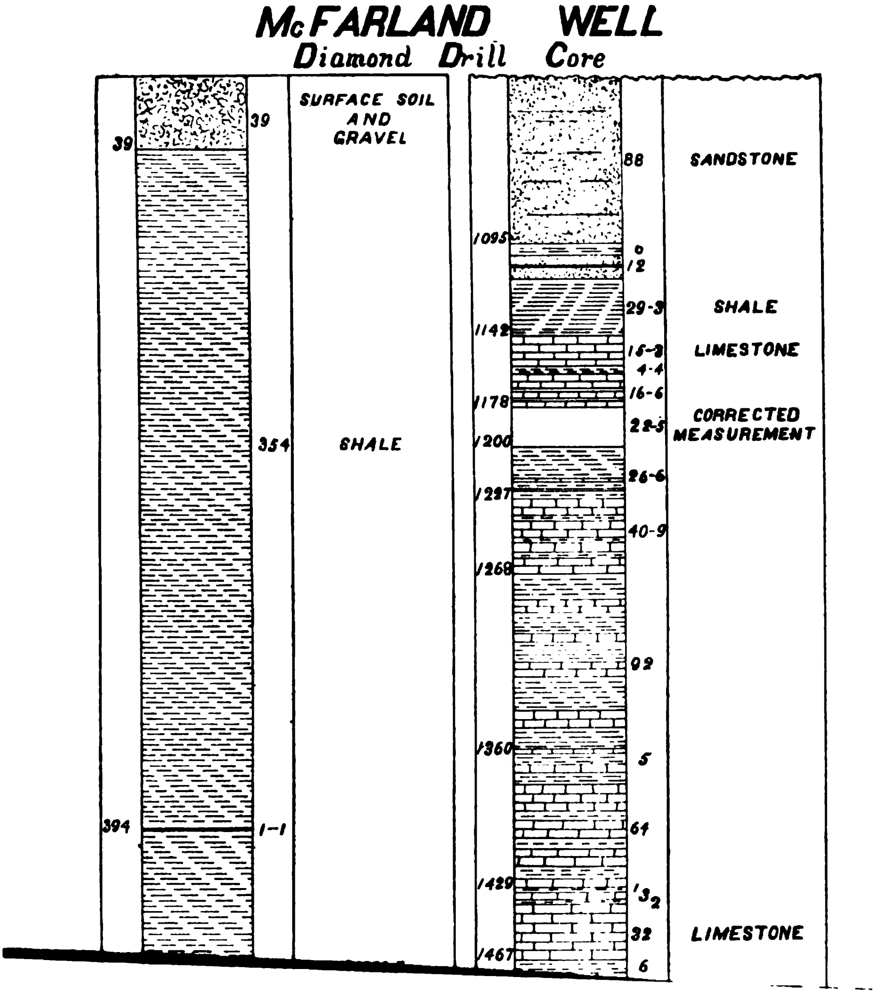

McFARLAND WELL
Diamond Drill Core
39
39
SURFACE SOIL
AND
GRAVEL
354
SHALE
394
1-1
88
SANDSTONE
1095
0
12
29-3
SHALE
1142
15-3
LIMESTONE
4-4
16-6
1178
CORRECTED
MEASUREMENT
22-5
1200
26-6
1227
40-9
1268
92
1360
5
64
1429
32
LIMESTONE
1467
6

PLATE XX.—The Leavenworth Well.

This well is of considerable interest on account of the light it throws upon the thickness of the Cherokee shales, which are here over 500 feet thick. The upper part of the drawing representing this well is taken from the record of the coal shaft because it was thought that it would be more reliable in detail than any of the drill records. It should be stated, however, that there was a close correspondence between the coal shaft record and the drill record of the well which was used for the lower part of the drawing. The strangest part of this record is 375 feet of hard white sandstone, as mentioned in Chapter II. This has been thought, possibly, to belong to the Mississippian limestone and that the flint rock of the limestone produced the so-called sand.

Scale: Vertical, 1 inch equals 100 feet.

PLATE XX.

LEAVENWORTH CITY WELL AND LANSING COAL SHAFT COMBINED

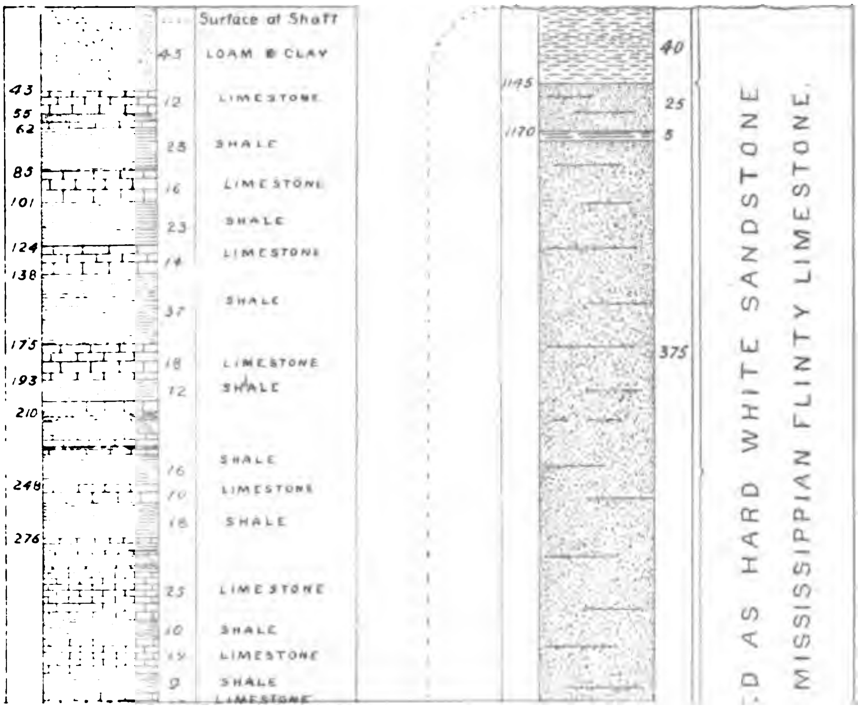


PLATE XXI.—The Anthony Well.

This well record is reproduced here because it has so important a bearing on the westward extension of the Permian along the southern part of the state. The well reaches a total depth of 2,335 feet. It passed through 551 feet of the Red Beds exposed at the surface; then 395 feet of blue shales; then 404 feet of the salt beds, reaching the limestone at 1,350 feet. From here to the bottom of the well, nearly a thousand feet, we have an unusually large amount of limestone, which aggregates 684 feet to 301 feet of shales. One cannot correlate the various limestone beds with corresponding beds in the Permian to the east. There can be no doubt, however, but that they are the Permian and Upper Coal Measure limestones. The heavy blue shale beds and salt beds lying above the limestone recall similar conditions, as shown in the McFarland well, where the uppermost members of the Upper Coal Measure limestones seem to be wanting.

Scale: Vertical, 1 inch equals 100 feet.

PLATE XXI.

ANTHONY WELL

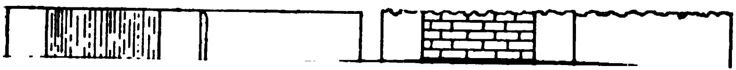


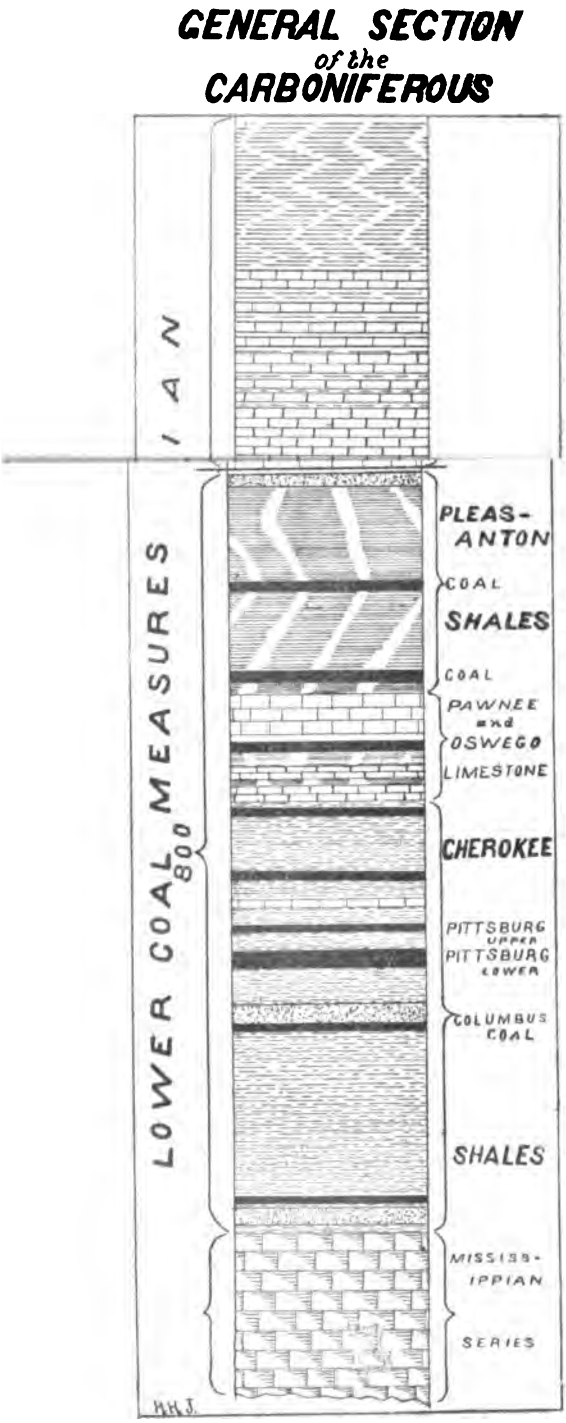
PLATE XXII.

This represents a generalized section of the Carboniferous, from the Mississippian to the top of the Permian. The total depth given is 3,545 feet. In making this estimate it was endeavored to use the mean thickness for the various formations. Had the maximum thickness been used it would have aggregated considerable more.

For further explanation see Chapter IX.

Scale: Vertical, 1 inch equals 100 feet.

PLATE XXII



GENERAL SECTION
of the
CARBONIFEROUS
IAN
LOWER COAL MEASURES
800
PLEAS-
ANTON
COAL
SHALES
COAL
PAWNEE
and
OSWEGO
LIMESTONE
CHEROKEE
PITTSBURG
UPPER
PITTSBURG
LOWER
COLUMBUS
COAL
SHALES
MISSISS-
IPPIAN
SERIES
W.H.J.

PLATE XXIII.

To accompany Chapter X.

A mound one mile south of Cherryvale. This represents the process of erosion with a thin limestone bed lying above a heavy shale bed. The limestone is plainly seen at the top of the mound (the Independence limestone), and the perfectly flat top which it has is due to the protection of the limestone cap. The bare places on the sides of the mound are places where the weathering away of the shales is so rapid vegetation cannot get started.

PLATE XXIII.

PLATE XXIV.

To accompany Chapter X.

A portion of the row of mounds one mile north of Cherryvale. The same limestone, the Independence, protects the summit of this mound which was shown in Plate XXI. Here the degradation of the shales on the south side of mound is more rapid than that in Plate XXI, and there is correspondingly a larger portion of the hillside void of vegetation.

PLATE XXIV.

PLATE XXV.

To accompany Chapter X.

A row of mounds beginning about three miles south of Cherryvale and extending towards Coffeyville four or five miles farther. The summits of these mounds are protected by the Independence limestone, the same one shown in Plates XXI and XXII. Near the left end of the figure one of the mounds is seen plainly standing out by itself, from which the protecting limestone is entirely removed, and which is already beginning to assume the rounded form produced by the weathering of soft materials.

PLATE XXV.

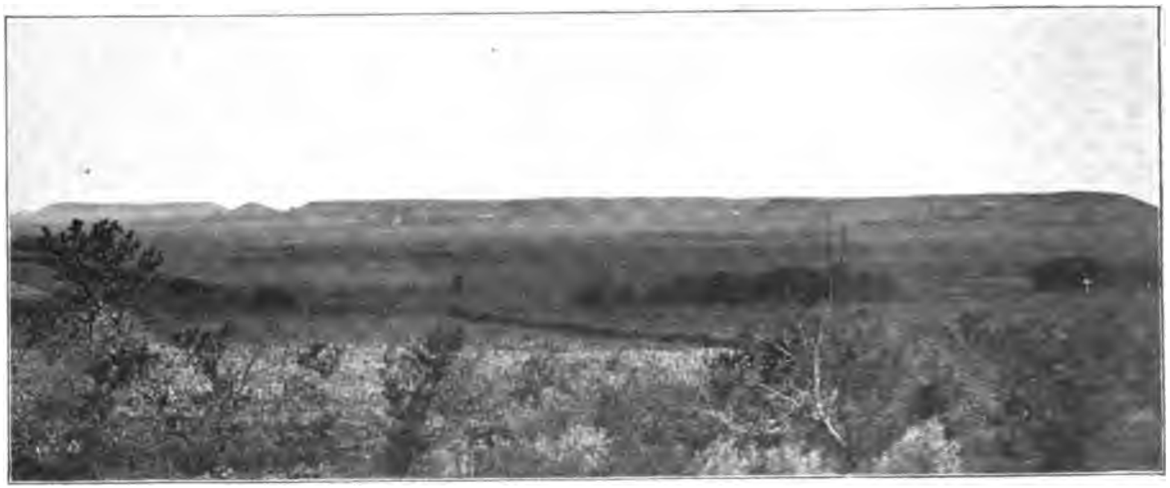


PLATE XXVII.

To accompany Chapter X.

A scene on the Kansas river, near Lawrence.

PLATE XXVII.

PLATE XXVII.

To accompany Chapter X.

A scene on the Kansas river, near Lawrence.

PLATE XXVII.

PLATE XXVIII.

To accompany Chapter X.

Blue Mount, Manhattan. This represents the eastern extremity of the high escarpment just north of the city of Manhattan. The Blue river passes to the right, and the Kansas river on the south. The high bluff is protected by the Cottonwood Falls limestone, as shown at the summit in the left hand part of the figure. This protection has been worn away near the middle of the figure and the valley has begun forming, which in the course of time will cause the right hand portion to become an isolated mound.

PLATE XXVIII.

PLATE XXIX.

To accompany Chapter X.

A scene along the north bank of the Kansas river, about six miles west of Manhattan.

PLATE XXIX.

PLATE XXX.

To accompany Chapter X.

Republican river bluff at Wakefield. This shows the Permian limestone on the bluff on the west bank of the Republican river about one-fourth mile above the village of Wakefield. The stratification of the heavy limestone beds is well represented and the surface soil and gravel above.

PLATE XXX.

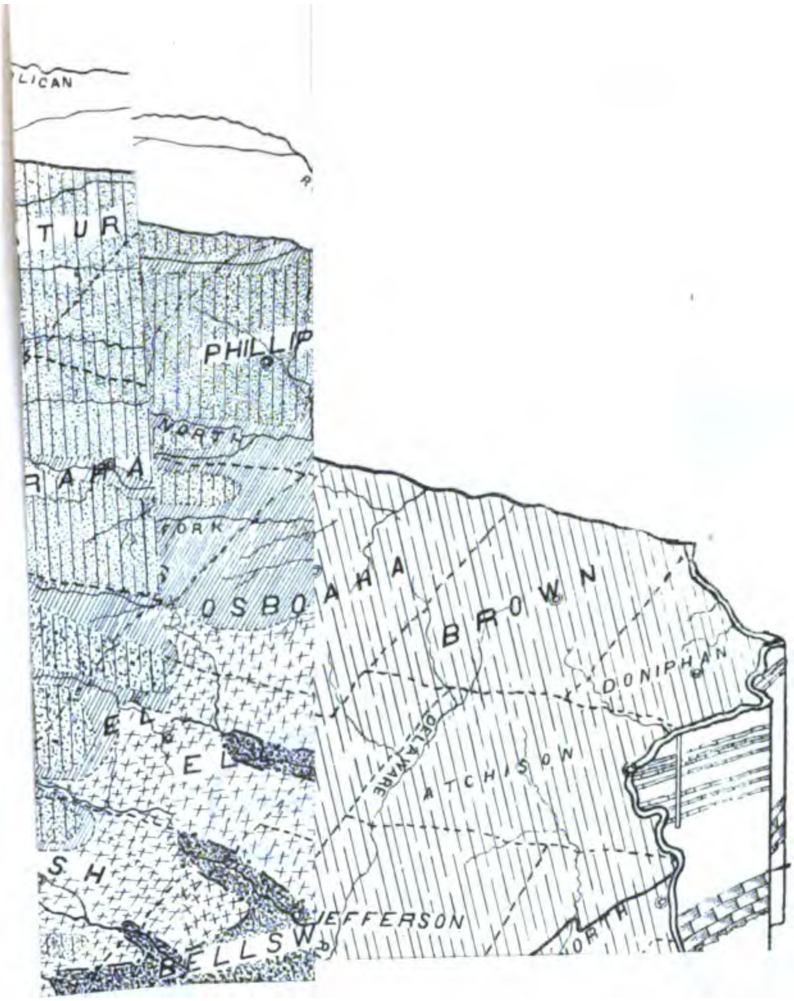
PLATE XXXI.

A Geologic Map of Kansas (preliminary). By Erasmus Haworth.

The Map is drawn in a semi-perspective manner so as to show the principal features of the stratigraphy along the east and south sides of the state. The evidence upon which such conclusions are based is largely that afforded by the deep wells, some of which are shown on the map. The areal extent of the different geological formations is shown by different styles of shading, all of which is explained in the legend on the margin of the map.

Since the plate was made it has been learned that the boundary line between the Permian and the Dakota in Harvey county should be a few miles nearer Newton.

Scale: Vertical, 1 inch equals 1,600 feet.


LICAN
TUR
PHILLIP
NORTH
FORK
OSBO
AHA
BROWN
DONIPHAN
DELAWARE
ATCHISON
JEFFERSON
NORTH
BELLSW

189